250 million years ago, did an asteroid nearly **END LIFE on EARTH?** p. 34

INSIDE pullout star charts

HOW TO observe the Sun p. 64

April 2008

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Is this the shape of the universe?

Cosmic inflation may be key to proving the cosmos has 6 extra dimensions p. 28

Our universe could be an offshoot of the strange shape below

Other universes could be tied to these extensions, called "throats"

This weird shape could conceal 6 extra dimensions of space

How molecules in space seed life in the galaxy p. 50

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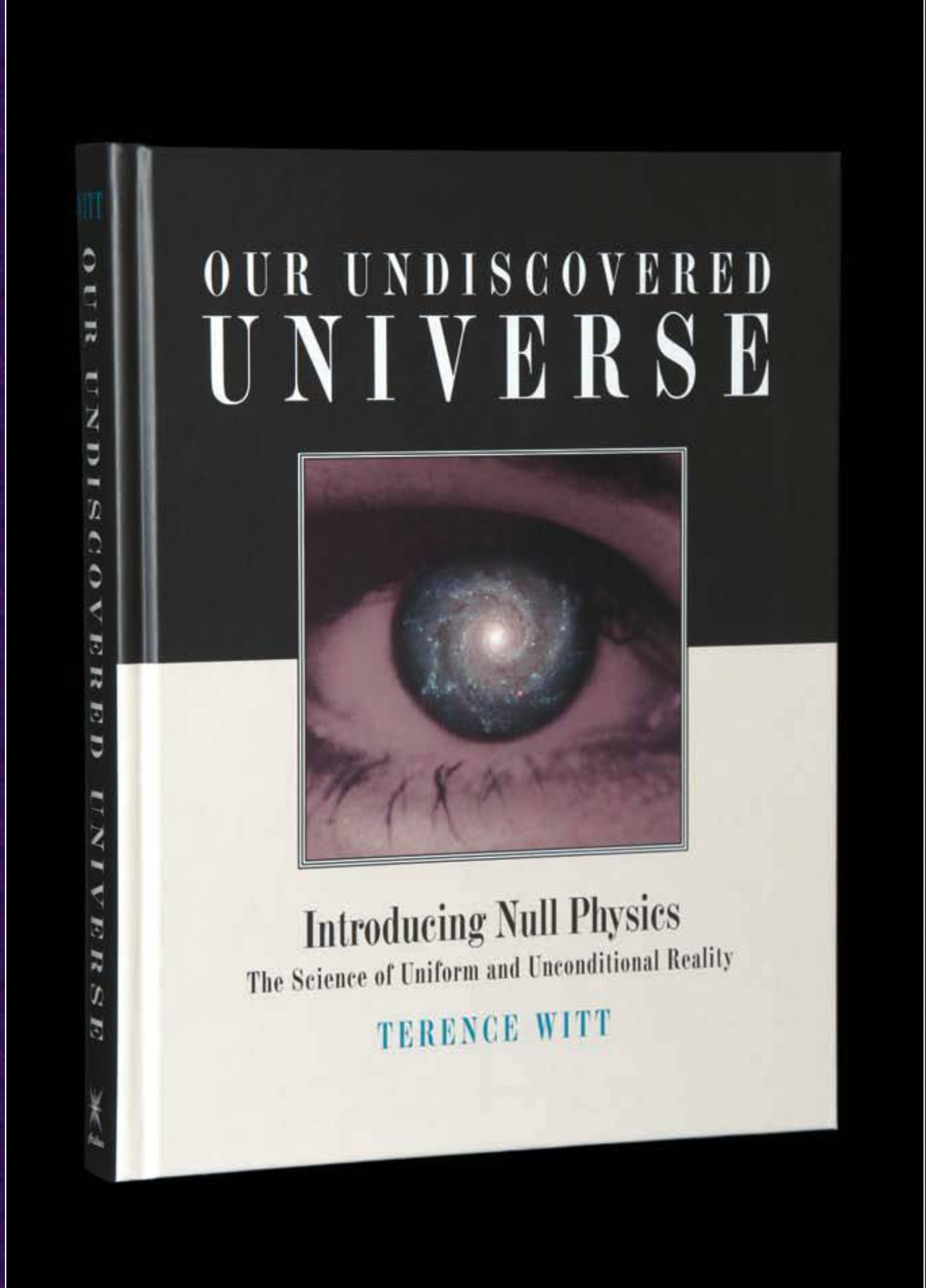
OUR UNDISCOVERED UNIVERSE
OUR UNDISCOVERED UNIVERSE
Introducing Null Physics
The Science of Uniform and Unconditional Reality
TERENCE WITT

Theoretical physics has been hopelessly stalled for over 30 years. Moribund. Ossified. The Standard Model of particle physics uses over 20 ad hoc constants, and no one knows why they are necessary or why they have the values they do. Quantum physics and general relativity remain utterly incompatible. Cosmologists haven't the foggiest idea what could have caused the Big Bang or what, if anything, came before it. And finally, after over 30 years of effort, string theory hasn't even achieved the status of *science*.

There is a very simple reason for this catastrophic, intractable mess. Theorists stopped asking *why* a long time ago. Without the *why*, the search for mathematical symmetries becomes numerology, not science. No telescope or particle accelerator, regardless of its size, is going to tell us *why* the universe is the way it is. When the *why*'s remain unanswered, there is no understanding. When there is no understanding, there is no progress. But this sad situation is about to change forever.

Our Undiscovered Universe is all about the *why*. It's an entirely new paradigm, a premise so powerful that it can finally answer the most important question of all: "*Why does the universe exist?*" This, in turn, reveals many of nature's secrets to a depth and clarity never before imagined.

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- Energy is a three-dimensional substance, and its most basic unit is time-distance^2.
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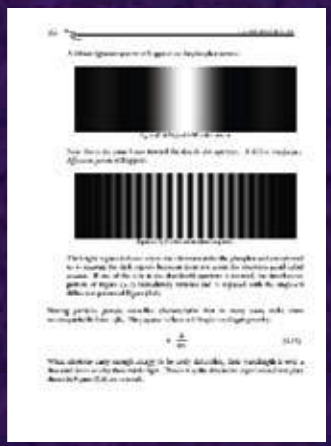
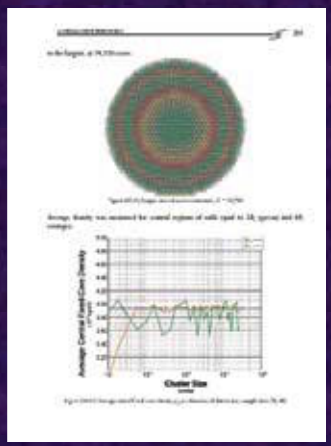
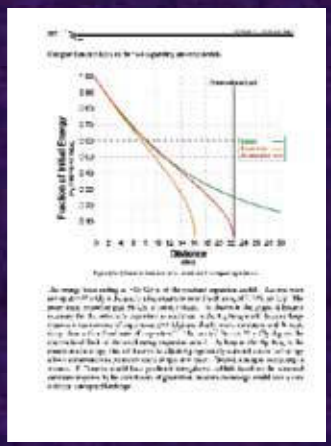

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VOL. 36, NO. 4

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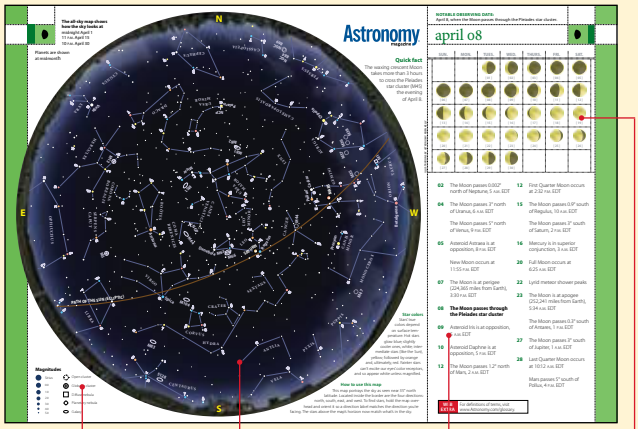

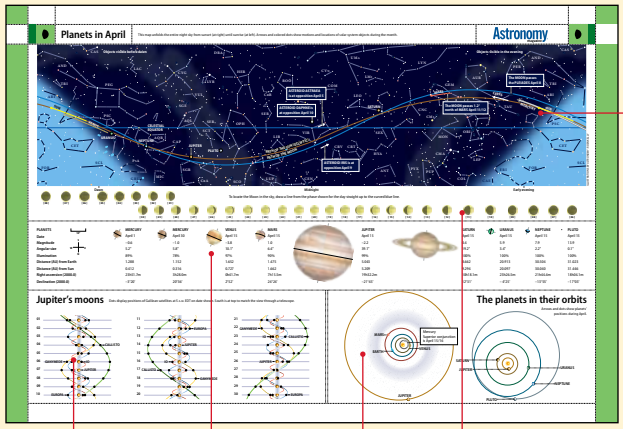

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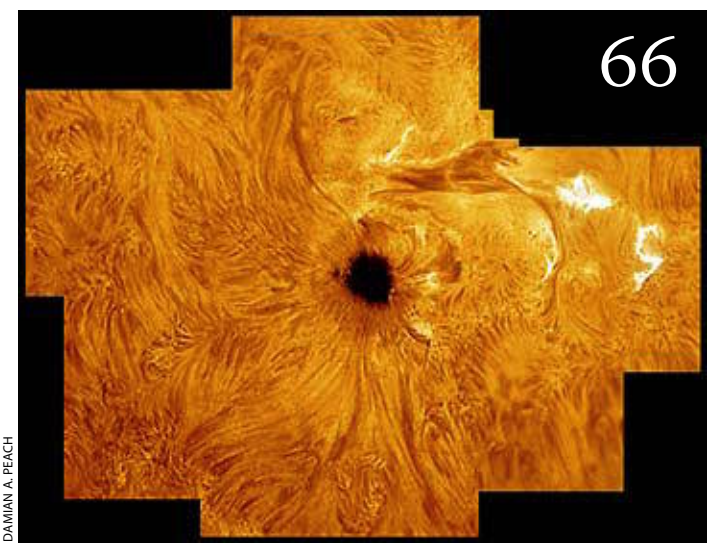

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The weirdest cosmology story ever

If you want the ultimate conversation

starter at the next cocktail party, ask someone about the latest on Calabi-Yau manifolds. Unless you're surrounded by mathematicians and theoretical physicists, you'll get some weird looks. The mathematical shape, thought to be incredibly tiny and complex, may be the key to hiding multiple dimensions that are "folded" alongside the three spatial dimensions and time that we're familiar with. Contributing Editor Steve Nadis' story, "Searching for the shape of the universe" (page 28), attacks the question headlong and will certainly be remembered as one of the strangest cosmological stories we've run in years.

"If string theorists are right," proclaims Lisa Randall of Harvard University, "everywhere in visible space — at the tip of your nose, at the north pole of Venus, at the spot above the tennis court where your racket hit the ball the last time you served — there would be a six-dimensional Calabi-Yau manifold of invisibly tiny size."

Physicists believe the manifold's geometry holds the key to understanding the laws of particle physics, gravity, cosmic inflation, and even dark energy.

Calabi-Yau manifolds not only could be significant structures on small scales, but also on large ones. The whole universe, or rather multiple universes, could be governed by the Calabi-Yau shape, with "throats," or extensions, protruding from them and containing individual universes including our own.

Cosmologists have good evidence that our universe underwent an early period of hyper-expansion that suddenly inflated the cosmos' size. Some now believe the interaction of two membranes, or "branes," produced inflation. This, in turn, left an imprint on the cosmic microwave background radiation. Astronomers are now busy comparing what they would expect to see from remnant branes with what they observe in the sky.

For now, the slow and precise work of science goes on, considering a whole new world of relationships, questions, and answers involving all the big, sexy topics of cosmology. Defining the shape of the cosmos may make the weirdest cosmology story ever told.

On a less scientific note, let me introduce our new editorial intern, Megan McChain, who accomplishes a variety of tasks around our office, always with a big smile. Megan is a junior at Marquette University in Milwaukee, where she is majoring in journalism and minoring in Spanish. She received the St. Ignatius Scholarship for students with high achievement. Occasionally, she writes articles for the *Marquette Tribune*.

She also volunteers as a tutor for grade-school children at the Hope House in Milwaukee. Some of her favorite activities are camping, water skiing, running, and rock climbing. Welcome, Megan!

Yours truly,

David J. Eicher
Editor

Astronomy

Volume 36, Number 4

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Subscriber-only web extras bring you additional research, interviews, photographs, and animations that our editors turned up while creating the magazine stories.

"Get a head start on the Hydra" p. 18
Go deeper into Hydra the Water Snake's western realm.

"How to find a Space Needle in a haystack" p. 20
Check out a Hubble image of the Pencil Nebula.

"Searching for the shape of the universe" p. 28
Find out more about Gary Shiu's work with hidden dimensions.

"Ask Astro" p. 56
Discover the difference between an asteroid and a comet.

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Scientists offer other theories of what caused the Great Dying.

"Did molecules from space seed life in the cosmos?" p. 50
Learn about the new ALMA telescope array in South America.

"How historic observatories will survive" p. 62
Read about a symposium aimed at saving historic observatories.

This month's top blogs

Editors put their spin on current events in the staff blog. You can share your opinions on news headlines and popular culture, too.

1 **SEEING THE LIGHT (OR NOT).** Activists in Brookhaven, New York, helped create light-pollution legislation. Would your community pass legislation to reduce light-polluted skies? **BY JEREMY McGOVERN**

2 **ECLIPSE MUSINGS.** A total solar eclipse is one of the most dramatic natural events anyone will experience. The Moon next covers the Sun August 1. **BY MICHAEL E. BAKICH**

RICHARD TALCOTT

Solar eclipse, July 1991

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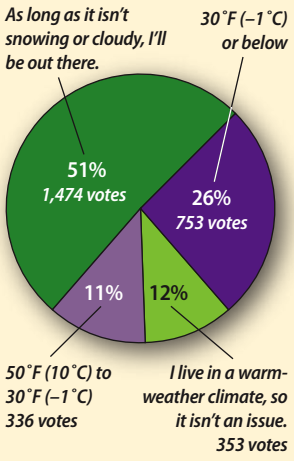
Beginning astronomers take note: Senior Editor Michael E. Bakich shows you how to identify celestial objects like a pro with Meade's mySKY.

Online poll results

How cold does it have to be for you to skip observing?



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Editor David J. Eicher interviews Melita Thorpe about *Astronomy*'s China tour to observe the 2009 solar eclipse.

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Senior Editor Michael E. Bakich explores deep-sky gems in the constellation Leo.

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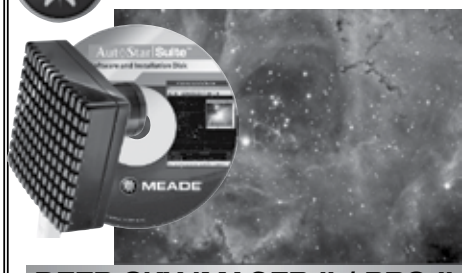

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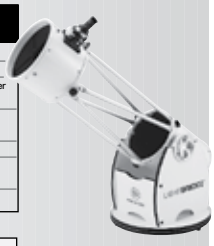

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More than one Pinwheel

In "The sky's Triangle" (November 2007),

Phil Harrington refers to the Pinwheel Galaxy as M33. But in "Making sense of galaxies" in the same issue (page 54), the illustration refers to M101 as the Pinwheel Galaxy. Can both be right? — **JIM VARLEY,** PACIFICA, CALIFORNIA

People commonly refer to both M33 and M101 as the Pinwheel Galaxy. There is no official designation for either, however. Either may be called the Pinwheel Galaxy. **— DANIEL PENDICK,** ASSOCIATE EDITOR

Seeing too far?

In "Why is the solar system cosmically aligned?" (December 2007), Dragan Huterer said the Big Bang occurred 13.7 billion years ago. He then went on to say the edge of the observable universe lies 45 billion light-years distant. How could a distance of 45 billion light-years develop in only 13.7 billion years? **— BOYD HOGAN,** CAMBRIA, CALIFORNIA

When we say "an object is 10 billion light-years away from us," we mean the light emitted by the object traveled a distance — as measured today — of 10 billion light-years on its way to Earth.

However, if an object is 10 billion light-years away, this does not imply that it took the light beam 10 billion years to travel this distance. This is because the universe is expanding and was smaller in the past.

The mile or kilometer the light beam crossed early in the history of the universe has stretched with time. At a later time, that 1 mile of distance traveled in the early universe becomes 2 miles, then 3 miles, etc. Therefore, an object's total distance from us in light-years, as measured today, is greater than the actual travel time as measured by a stopwatch multiplied by the speed of light.

This is why the most distant object we can see today would be about 45 billion light-years away, even though its light has been "en route" to Earth for only 13.7 billion years. **— DRAGAN HUTERER,** DEPARTMENT OF PHYSICS, UNIVERSITY OF MICHIGAN, ANN ARBOR

Life in space

In "50th anniversary of first microbes in orbit" (November 2007), James Oberg said life-forms first hitched a ride on space-faring hardware November 3, 1957, when the Soviets launched the dog Laika into orbit. This statement is not correct.

The United States launched some fruit flies — the first animals in space — aboard a V2 rocket in 1947. Even though the fruit flies didn't reach orbit, as did Laika, they still made it to the edge of space. **— JEFFREY MARA,** CONCORD, MASSACHUSETTS

Black-hole secrets

This is in reference to Bob Berman's letter in the November 2007 issue about black holes. From what I read, black holes form after the explosive collapse of a sufficiently massive star in a supernova. Since supernovae can occur in the present, how can you say that black holes cannot also form in the present? Are you saying that if a supernova occurs today or in the future, no black hole can be the result? **— SHAWN TRUEMAN,** ST. CLOUD, MINNESOTA

A black hole can form in the present, but only from the black hole's point of view. An outside observer can never witness such an event. From our frame of reference, the star collapses up to a point, but stops just short of being a black hole with a bona fide event horizon and singularity. It remains frozen in that "almost black-hole" state.

It achieves full black-hole status in our universe only after infinite time has elapsed, which means "never." Different "reference frames" of this nature form the mathematical and logical bases of Einstein's relativity theories of 1905 and 1915. **— BOB BERMAN,** CONTRIBUTING EDITOR

THE SPIRAL GALAXY M101 looks like a pinwheel, but it isn't the only object called by that name. NASA/ESA

Thanks for the page numbers

Congratulations for having the most visually attractive and "fun-to-receive" magazine out there. And thank you for putting page numbers next to all the stories listed. I can't tell you how many times, with other magazines, I wasn't even able to find a story mentioned on the cover. But it's never a problem with *Astronomy*. Your efforts are appreciated. **— MICHAEL MACELLETTI,** BETHEL, CONNECTICUT

We welcome your comments. Send letters to Astronomy *Letters, P. O. Box 1612, Waukesha, WI 53187; e-mail to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.*

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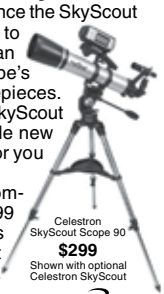

Celestron SkyScout Scope 90 **$299** Shown with optional Celestron SkyScout

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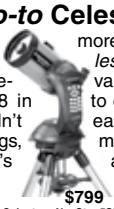

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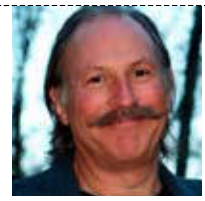
BY BOB BERMAN



Are we done yet?

Some people worry about an object from space doing us harm. It's the dinosaur thing — a legitimate link between our own well being and the larger universe.

In my December 2007 column, I dissected a popular but bogus Armageddon-from-the-sky scenario based on Mayan calendar mumbo jumbo. Now let's examine a very different kind of scare circulating on the web, one that involves real astronomy. It sounds terrifying: A killer asteroid is heading our way! The doomsday year is 2036, and, in case you're concerned, here's the scoop.

The asteroid 99942 Apophis is real enough. A famous astronaut, Buzz Aldrin, is raising awareness about it. He and I chatted about it on the phone a year ago because he's genuinely concerned Apophis might collide with our planet. That's a bit surprising, because the chance of an impact is just one in 45,000. Is such a minuscule astro-peril even worth thinking about? Apparently it is. Last fall, researchers at MIT cared enough about Apophis to determine its composition.

The general makeup of asteroids is well known: They're stony and metallic, very different from the flimsy comet ices that produce meteor showers. That's why most meteors harmlessly disintegrate in the atmosphere. But some of the sporadic nightly "shooting stars" between midnight and dawn do hit the ground — because they're asteroid fragments.

It's easy to calculate the damage wrought by an impacting object because it derives mainly from just two factors. The first is its speed. Meteors typically enter our atmosphere at 20 to 40 miles per second. The second factor is mass. The meteors routinely seen in the night sky weigh less than a gram. But rarer incoming meteoroids can easily weigh a ton, like the intruder that broke apart over a Chicago suburb March 26, 2003.

Fortunately, if a meteoroid weighs less than 8 tons — and nearly all of them do — air friction robs most of its initial speed. Our thick lower atmosphere slows it to a terminal velocity of 200–300 mph. That's the speed nearly every meteor travels when it hits the ground. It's enough to penetrate a roof. Since 2002, meteors have ended up on the floors of at least seven homes, including two in the United States. And yes, they then belong to the homeowner.

APOPHIS COULD KILL
50 million people, but not wipe out the world.

If a meteoroid weighs more than 100,000 tons — and Apophis, 3 times the length of a football field, certainly does — our atmosphere can't slow it down in the slightest. It retains all its cosmic velocity as it slams into the ground at 90,000 mph, give or take.

No wonder some folks are concerned.

On Friday the 13th of April 2029, Apophis will whiz very close to Earth, about 10 times nearer to us than the Moon. It will easily be visible to the naked eye as a 3rd-magnitude star, its dramatic motion obvious to backyard stargazers. Apophis will pass just 22,000 miles from our surface, closely matching the height of geosynchronous satellites. It could even knock one to smithereens.

Then the fun begins, as Earth's gravity changes the asteroid's orbit. If Apophis passes through a particular ¼-mile-wide "window" of space during its 2029 encounter, its orbit could be altered so that it collides with us 7 years later. We won't know this until its 2029 encounter has come and gone.

Knowledge of this asteroid's composition could help us decide how to deal with it, should further refinements of its orbit indicate that it might indeed be on a collision course. This past October, Richard Binzel, professor of planetary sciences at MIT, said, "We've got to know the enemy," as he presented new findings about Apophis to the American Astronomical Society.

Working with graduate students, Binzel used spectral analysis to measure how Apophis reflects light of various wavelengths, compared to meteorites collected on Earth. The researchers showed that the asteroid's minerals perfectly match those of type LL chondrites, which comprise only 7 percent of the meteorites that fall on our planet.

Apophis could totally destroy an area larger than Texas, with serious damage rippling over a much wider zone if it hits the sea and creates a tsunami. Regions on the opposite side of Earth would remain safe: This is nothing like the global devastation wrought by the K-T meteor that struck the Yucatán coast 65 million years ago. Apophis could kill 50 million people, but not wipe out the world.

Scared? I'm not — not in the least. Remember, the odds are 45,000-to-one against any collision at all. But if your brand of paranoia likes to focus on low-likelihood, high-velocity drama, well, you've come to the right century.

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BY GLENN CHAPLE

Reap the awards of amateur astronomy

Ah, the rewards of stargazing! Cool, fresh night air. A soothing chorus of crickets in a nearby meadow. Overhead, a canopy of sparkling stars. A starlit evening's serenity does much to alleviate the stress of everyday life. We return indoors with a welcome feeling of renewal.

As if these intangibles weren't enough, we can also look forward to more material rewards. Some astronomical organizations present certificates to members who demonstrate proficiency in particular disciplines of amateur astronomy.

An award certificate can help launch the beginner into a lifetime of skygazing or entice the expert to try something new. For example, the American Association of Variable Star Observers (AAVSO) recognizes members who reach milestones in their total contributed variable-star observations.

Certificates are awarded for 10,000 observations, 25,000, 50,000, 100,000, and beyond. I hope to reach 100,000 sometime within the next 6 years.

Do I need awards to keep me actively observing variable stars? Not really. But the AAVSO's certificate program helped me break down a lofty goal into reachable steps.

The Astronomical League (www.astroleague.org) also offers certificates to members who participate in their observing clubs. One that caught my attention was the Double Star Club.

I was an avid double-star observer in my early years as an amateur astronomer but then abandoned them in favor of variable stars. Enticed by the opportunity to receive a double-star certificate, I observed and sketched the 100 pairs on the Double Star Club list. In the process, I reacquainted myself with many of my favorite double stars, some of which I hadn't viewed in decades.

For youngsters just getting into astronomy, the Astronomical League offers the Sky Puppy Club. Adult novices are encouraged to try the Constellation Club or the Universe Sampler Club. Veteran skygazers can opt for the Messier Club or tackle the Mount Everest of all certificate programs, the Herschel 400 Club. If you're an urban dweller encumbered by light pollution, the Astronomical League hasn't forgotten you. Try its Urban Club.

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THE REWARDS for stellar achievements in amateur astronomy include peer recognition. COURTESY GLENN CHAPLE

Other Astronomical League clubs recognize observations of satellites, the Sun, Moon, planets, asteroids, comets, meteors, and a variety of deep-sky objects. For more information about the Astronomical League and its observing clubs, contact National Observing Program coordinators Mike Benson (ocentaurus@aol.com) or Aaron Clevenson (aaron@clevenson.org).

I urge every astronomy club to implement an award program that encourages its members to observe. You could establish one of your own. The Saguaro (Arizona) Astronomy Club (www.saguaroastro.org) offers an award program that combines some of the Astronomical League's observing clubs with lists drawn up by its own members.

Although some observers regard an award program as a materialistic enterprise, others thrive on tangible rewards.

Astronomy Senior Editor Michael Bakich discusses the pros and cons of observing awards in his book *The Cambridge Encyclopedia of Amateur Astronomy* (Cambridge University Press, 2003). He highlights the structure of such programs and their potential for coaxing us into areas of amateur astronomy we might otherwise never explore. However, he cautions exaggerating the significance of award programs. Bakich writes, "Please don't tell me that simply because Observer A has a Herschel 400 certificate s/he is a better observer than Observer B."

If amateur astronomy were merely a "paper chase," most of us would have long ago given up on the hobby. I like to think of a certificate program as the reward that lures us out. It's the star-filled sky — the ultimate reward — that keeps us there.

Questions, comments, or suggestions? E-mail me at gchaple@hotmail.com. Next month: Upgrading a low-quality telescope. Clear skies!

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BY PHIL HARRINGTON

Get a head start on the Hydra

With winter giving way to spring, the promise of warmer nights is always a reason to rejoice. But I'm a little blue this month over the loss of those great winter stars in Orion and Canis Major. But don't worry — plenty of interesting binocular targets await you during breaks in those

April showers. This month, we'll tour Hydra the Water Snake. You can see Hydra creeping above the southern horizon. Hydra is the longest constellation, spanning nearly 100° of sky. It bridges the empty gulf between winter's brilliant stars and the dazzling summer Milky Way. This month, we'll concentrate on Hydra's head and western half.

Let's begin at Hydra's brightest star, **Alphard** (Alpha [α] Hydrae). To find Alphard by eye, start near the zenith at the Big Dipper. Trace a line southward from **Megrez** (Delta [δ] Ursae Majoris) to **Phecda** (Gamma [γ] Ursae Majoris) in the "bowl." You'll soon arrive at **Regulus** in Leo the Lion. Keep on going, and you'll reach a lone star farther to the southwest. It's aptly named Alphard, from the Arabic *al-Fard al-Shuda* for "the serpent's solitary one."

Alphard is an orange giant similar in size and nature to better known Arcturus and Aldebaran. Alphard is farther from Earth than these stars, so it appears less radiant. Still, with binoculars, you can easily perceive Alphard's orangish hue.

Northwest of Alphard, Hydra's lopsided head also shows its true colors through binoculars. All five stars fit into the same binocular field, making it easy to compare their colors. Defocusing the image slightly will accentuate the differences. The northeastern star, **Zeta** (ζ), should appear orange. **Epsilon** (ε) and **Delta** (δ) are both white, **Sigma** (σ) is orange, and **Eta** (η) is blue-white.

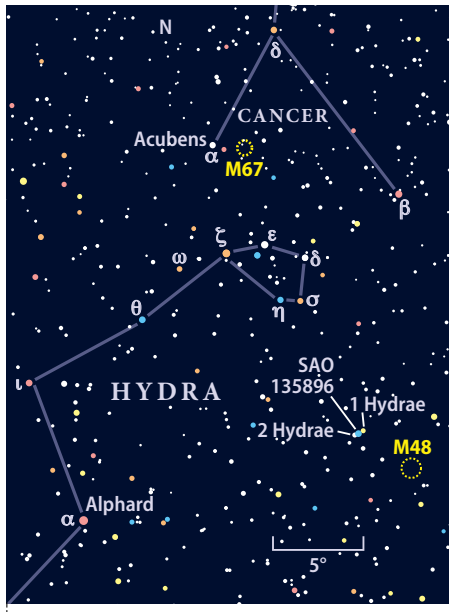
Hydra's head is a handy asterism for finding two oft-ignored star clusters. Imagine the stars Zeta, Epsilon, Delta, and Eta as forming a northward-pointing arrow. It aims squarely at **M67** (NGC 2682) in Cancer.

M67 lies just west of the 4th-magnitude star **Acubens** [Alpha (α) Cancri]. M67 looks like a faint blur punctuated by a few dim stars through my 10x50 binoculars. The background glow created by the cluster's unresolved members seems irregular, with brighter concentrations toward the east and southwest. Recently, Croatian amateur Ante Perkovic described M67 through his 12x45 binoculars as "looking like it has a bar through the middle, like a barred spiral galaxy." Can you see M67's "bar?"

Backtrack now to Hydra's head. Draw a line from Epsilon through Sigma and continue southwest. Watch for a diagonal line of three stars: **1 Hydrae**, **SAO 135896**, and **2 Hydrae**. Continue southwest a little farther and you'll come to **M48** (NGC 2548).

M48 is impressive in all binoculars. Through my 10x50s, it looks like a dim haze of unresolved starlight larger than the Full Moon. From my suburban backyard, I can make out the group's brightest stars, shining at 8th magnitude. Darker skies add a few fainter points near the cluster's center.

Higher-power binoculars resolve M48 into dozens of stars. A tight grouping of eight suns resembling a capital A highlights the center. Outliers give the cluster an overall triangular appearance, looking something like an arrowhead aimed east.



HYDRA THE WATER SNAKE meanders across the sky. Here are the stars of its head and western half. *ASTRONOMY:* ROEN KELLY

For nearly 2 centuries, M48 was "lost." The problem began in 1771, when Charles Messier discovered the cluster but incorrectly recorded its location. Where did it go?

In 1934, Romanian astronomer Oswald Thomas finally solved the case of the missing cluster. T. F. Morris of the Royal Astronomical Society of Canada independently verified Thomas' observations in 1959. Thomas and Morris both concluded that Messier's description closely matched NGC 2548, even though it is 2.5° south of Messier's original position. As a result of their research, we now consider both clusters one and the same.

Next month, we'll survey Hydra's eastern half. Till then, remember that two eyes are better than one.

WEB EXTRA Check out more targets in the Water Snake's western realm at www.Astronomy.com/toc.

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BY STEPHEN JAMES O'MEARA

How to find a Space Needle in a haystack

In my last two columns, I explained how to observe the nebula Barnard's Loop in Orion. This 10°-wide emission nebula, also known as Sharpless 2-276, may be the only supernova remnant visible to the unaided eye. This month, I'm taking you to the other extreme. I'd like observers,

THE CATACLYSMIC EXPLOSION of a star some 11,000 years ago formed the Vela Supernova Remnant, a cloud of gas and dust 800 light-years from Earth. AXEL MELLINGER

especially those in the southern United States and beyond, to seek out the tiny emission nebula NGC 2736 in Vela.

This needle of light is the brightest filament in the Gum Nebula, the vast (nearly 40°-wide) remains of a star that went supernova about 11,000 years ago. Lying at a distance of about 815 light-years, NGC 2736 marks the eastern boundary of the supernova's expanding shock wave. The shock wave is plowing into the nebula at a speed of roughly 400,000 mph (644,000 kilometers per hour), causing it to glow.

NGC 2736 is popularly known as the Pencil Nebula. But I prefer to call it the Space Needle. Not only is the nebula long and thin, but spotting it through a small telescope from the Northern Hemisphere is as difficult as finding that proverbial needle in a haystack — the rich Vela Milky Way.

Herschel finds the needle

The English astronomer John Herschel (1792–1871) discovered the Pencil Nebula in 1835, using an 18¼-inch, speculum-mirror reflector. He had set up the instrument the previous year to survey the southern skies from the Cape of Good Hope.

Herschel did not sweep the sky with his scope. Instead, he let the sky drift through the stationary 15' field of an 180x eyepiece. As I explained last month, setting an object in motion sweeps light across the retina. This continually activates night-sensitive rod cells and keeps the brain on high alert.

Herschel described the new nebula as an "extraordinarily long narrow ray of excessively feeble light." (For this reason, NGC 2736 is also more appropriately known as Herschel's Ray.) He found the object's northeastern end brighter and narrower than its southwestern end, and he estimated the entire object's length to be at least 20'.

The hunt begins

If you've never heard of NGC 2736, you're not alone. Many popular star charts and atlases do not include it. A contributing factor may be that John Dreyer of Armagh Observatory misidentified NGC 2736 as a galaxy (seen edge-on, of course) in his 1888 New General Catalogue of Nebulae and Clusters of Stars. He also did not provide a magnitude or size for the object.

The 1973 *Revised New General Catalogue (RNGC)* repeated Dreyer's error, as did the 1988 version, *NGC 2000.0*. California amateur Steve Gottlieb straightened out NGC 2736's identity in a paper, "Corrections to the *RNGC*: 5," in the January 1992 *Webb Society Quarterly Journal*.

NGC 2736's epoch 2000.0 coordinates are right ascension 9h00m, declination –45°57', which places it about 2¾° southwest of the 2nd-magnitude star **Lambda (λ) Velorum**. If you're in the Northern Hemisphere, begin your hunt by locating 2nd-magnitude **Eta (η) Canis Majoris** in the Big

Dog's tail. Now look about 13° southeast for 2nd-magnitude **Zeta (ζ) Puppis**.

Zeta Pup marks the northwest corner of a near-isosceles triangle that includes two other 2nd-magnitude stars: the beautiful multiple star **Gamma (γ) Velorum** 7½° to the south-southeast, and **Lambda (λ) Velorum** nearly 12° to the east-southeast.

Zeroing in

Once you confirm 4th-magnitude Lambda Velorum, look about 3¼° south-southwest for c Velorum. Two roughly 7th-magnitude stars flank c Velorum, one to the north-northeast and one to the south.

Center c Velorum in your telescope, then use the finder chart below to zero in on your target. From c Velorum, move 20' north-northeast to 7th-magnitude Star A, then make a slow and careful sweep 1° due north to 8th-magnitude Star B.

Star B marks the northeast corner of a 40'-wide trapezoid of suns of near-equal magnitude. The northeastern end of NGC 2736 is just a few arcminutes west of Star C, which marks the trapezoid's southwestern corner. Look for a hyperfine thread, oriented north-northeast to south-southwest, with a sharp eastern edge. Congratulations — you've found the Space Needle!

THE PENCIL NEBULA (NGC 2736) is part of the huge Vela Supernova Remnant, located in the southern constellation Vela. NASA/HUBBLE HERITAGE TEAM (STScI/AURA)

At the Needle

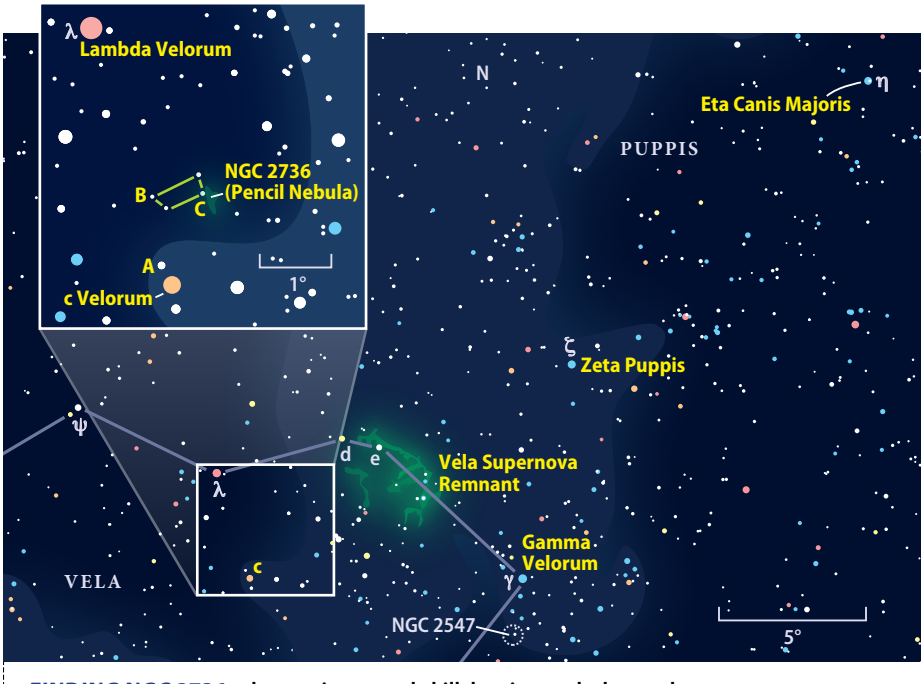
NGC 2736's bright northeast region stands out best in most telescopes. It's about 10' long, making it about twice the length and half the width of NGC 5907 (Draco's 11th-magnitude, edge-on Splinter Galaxy) or 20-percent longer and 30-percent thinner than 10th-magnitude NGC 4565, the famous edge-on spiral galaxy in Coma Berenices.

But unlike these galaxies, whose disks burn with the glow of concentrated starlight, NGC 2736 is merely a "braided" wisp of nebulous matter. Like the nebulous fibers in the Veil supernova remnant in Cygnus, NGC 2736 emits strongly at the wavelength of doubly ionized oxygen, so an oxygen-III (OIII) filter will help NGC 2736 stand out against the surrounding Milky Way.

Barbara Wilson of Houston has spied NGC 2736 several times from her home state. Through her 20-inch reflector and an OIII filter, she says the nebula "looks similar to the northern portions of the Veil Nebula, as seen without a filter. It also shows some wispy filaments and mottled structure." Gottlieb agrees. He "easily picked up" NGC 2736 in his 13.1-inch reflector at 105x while observing from Costa Rica. He called it "a thin splinter of light . . . with a weak filamentary structure and variations in brightness, similar to one of the fainter filaments in the Veil nebula."

Through my 5-inch f/5 refractor and 13mm eyepiece, NGC 2736 is just visible without a filter. Seeing the Needle required time, tube tapping, breathing and relaxation techniques, and using extreme averted vision. Interestingly, the brightest aspect of the nebula was not the Needle but the patch of emission nebula just west of the 11th-magnitude star that kisses the midpoint of NGC 2736's bright northeast segment.

I'd love to hear about what you see when you observe NGC 2736. Send your reports to me at someara@interpac.net.



FINDING NGC 2736 takes patience and skill, but is worth the work. *ASTRONOMY:* ROEN KELLY

WEB EXTRA Zoom into a Hubble shot of the Pencil Nebula at www.Astronomy.com/toc.

On top NASA's Ulysses spacecraft reached the highest point in its orbit over the Sun's north pole January 14. It's the craft's third such polar orbit in 18 years.

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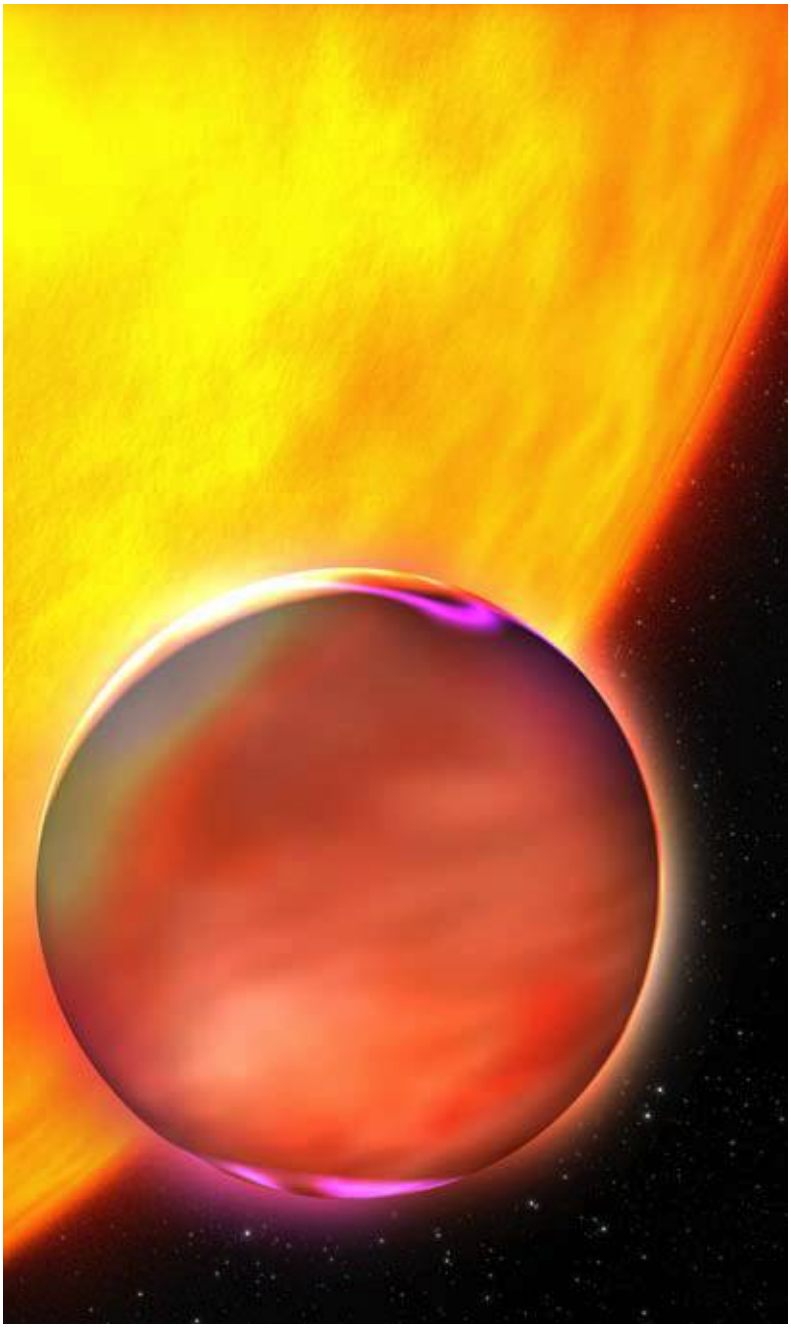


HIGH-ALTITUDE HAZE. The haze surrounding extrasolar planet HD 189773b, shown crossing in front of its parent star in this artist's concept, may produce red sunsets. ESA/NASA/FRÉDÉRIC PONT (GENEVA UNIVERSITY OBSERVATORY)

Hubble gazes at red alien sunsets and "star spots"

Astronomers used the Hubble Space Telescope to detect what may be an alien planet's reddish sunset haze. The planet, HD 189773b, is a gaseous "hot Jupiter" world slightly larger than its namesake in our solar system.

The exoplanet passes in front of, or transits, its parent star. Its light passes through the edges of HD 189773b's atmosphere twice per orbit. The starlight carries information about the planet's atmospheric gases. A spectrograph in Hubble then allows astronomers to determine the mix of gases that produced HD 189773b's unique light fingerprint, or spectrum.

Based on the spectral analysis, astronomers infer that HD 189773b's atmosphere contains a haze of tiny particles — possibly iron, silicon, and aluminum oxide — at an altitude of about 625 miles (1,000 kilometers).

The team, led by Frédéric Pont of the Geneva University Observatory in Switzerland, also detected cool regions, or "star spots," on the parent star. One particularly large star spot measured 50,000 miles (80,000 km) across — more than 6 Earths wide.

The observation is an incremental step toward probing the atmosphere of an earthlike planet, Pont says. Such observations might reveal evidence of life processes. **— DANIEL PENDICK**

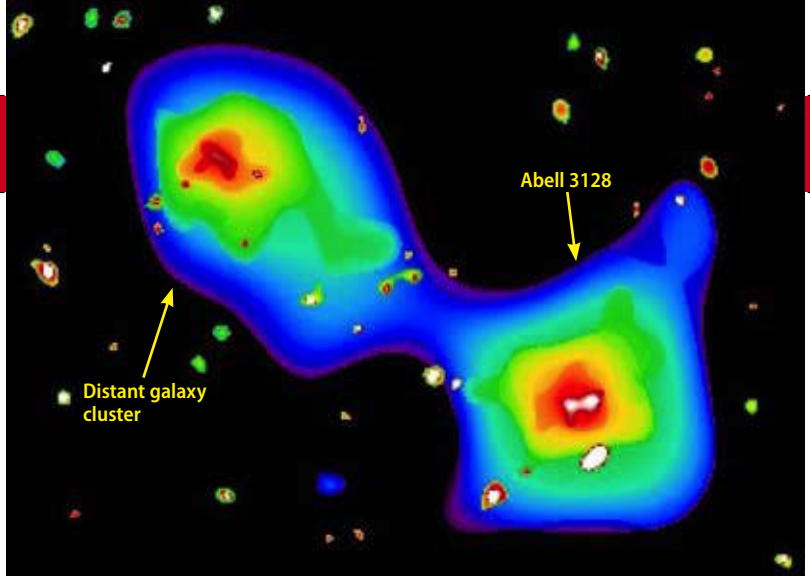
26

24 A view to a launch

25 Spots and flares mapped on Sun-like star

26 Mars likely had water

26 Rotating radio star mystery solved



TWO-FOR-ONE CLUSTERS. To astronomers' surprise, two bright X-ray regions thought to be portions of the same galaxy cluster, Abell 3128, are actually two separate clusters. ESA/XMM/EPIC/SRON (N. WERNER ET AL.)

Hide-and-seek galaxy surprises astronomers

The XMM-Newton X-ray satellite exposed a cluster of galaxies hidden behind another cluster. The newly discovered galaxy group appears to be just as bright as the obscuring cluster, but 6 times farther away.

Previously, astronomers perceived the clusters as two regions within the same galaxy cluster, named Abell 3128. The regions shone equally bright in X rays and were the same size.

However, spectral analysis showed the regions contain gas with different chemical compositions. This made no sense, assuming the regions were part of the same galaxy cluster and nestled within the same gas cloud.

XMM-Newton observations contradicted astronomers' assumptions. One blobby region was, in fact, the galaxy cluster Abell 3128. The blob next to it, however, was a totally different cluster located 6 times farther away — about 4.6 billion light-years — than Abell 3128.

The astronomers reported their findings in the October 2007 *Astronomy and Astrophysics*. **— D. P.**

"Death star" blasts neighboring galaxy

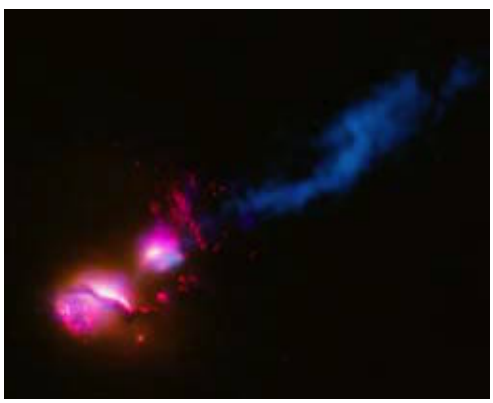
Astronomers have discovered the loose cannon of the cosmos: a galaxy aiming a high-energy jet at a nearby galaxy. The galaxies orbit each other in a system collectively known as 3C 321. They are about 20,000 light-years apart.

Observations with the Chandra X-ray Telescope show both galaxies possess massive black holes in their centers. But the larger galaxy of the two emanates a powerful jet of radiation and fast-moving particles, and it's skewering its companion. The team's findings appeared in December's *The Astrophysical Journal*.

"We've seen many jets produced by black holes, but this is the first time we've seen one punch into another galaxy like we're seeing here," says Daniel A. Evans, a scientist at the Harvard-Smithsonian Center for Astrophysics and lead astronomer of the study. "This jet could be causing all sorts of problems for the smaller galaxy it is pummeling."

Probing the "death star" galaxy was an international effort. Participating scientists used NASA's major orbiting observatories (Chandra, the Hubble Space Telescope, and the Spitzer Space Telescope) as well as ground-based instruments at the Very Large Array telescope in Socorro, New Mexico, and the Multi-Element Radio Linked Interferometer Network (MERLIN) telescopes in the United Kingdom.

The energy and accelerated particles in the jet are powerful enough to fry the atmospheres of any planets in the receiving galaxy, the astronomers noted. The jet could, for example, strip away any protective ozone layer. On the plus side, the jet could ignite star formation in its neighbor. **— D. P.**



X RAY: NASA/CXC/CFA/D. EVANS ET AL.; OPTICAL/UV: NASA/STScI; RADIO: NSF/VLA/CFA/D. EVANS ET AL.; SSTFC/JBO/MERLIN

DEATH STAR. The black-hole jet from one galaxy (left) slams into a neighbor. X rays in the jet extend outward to the right (purple), as captured by the Chandra X-ray Telescope.

QUICK TAKES

EXOPLANET AIR
Astronomers at the University of Texas in Austin detected an atmosphere on an alien planet for the first time using a ground-based telescope.

SKY QUAKE
NASA's fleet of five THEMIS satellites observed an auroral surge over Alaska March 23, 2007. The storm's total energy equaled that of a magnitude 5.5 earthquake.

NEXT COMET, PLEASE
The Deep Impact spacecraft is heading for a 2010 rendezvous with Comet Hartley 2 after its successful mission to Comet Tempel 1 in 2005.

DIGITAL MILKY WAY
An international consortium of astronomers released the first comprehensive digital optical survey of the Milky Way December 10.

ONWARD, VOYAGER
The Voyager 2 space probe crossed the edge of the Sun's influence in space in December. It now joins Voyager 1 in interstellar space.

INSIDE THE MOON
NASA announced the $375 million GRAIL mission December 10. Twin satellites will measure the Moon's gravity to map its interior in 2011.

LOFAR FIRST LISTEN
The LOFAR radio telescope heard its first radio waves in December. The instrument's first working antenna station is in the Netherlands.

FAST SATELLITE
Engineers at NASA's Goddard Space Flight Center built a $4 million microsatellite, FastSat, in a record 10.5 months.

TEACHING STARS
The International Astronomical Union launched a free quarterly journal for science educators in October: *Communicating Science to the Public*.

STAR BURST
Radio astronomers observed a distant galaxy forming new stars at a rate of 4,000 per year. That's 1,000 times the rate in our Milky Way Galaxy.

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A view to a launch

Russia's newest launch site promises to deliver many satellites into orbit, and some of them will make interesting targets for amateur space-watchers. Two of the satellites, inflatable-habitat prototypes built by Bigelow Aerospace in Nevada, already have become medium-difficulty favorites for sky-watchers. More will follow.

Watching a launch from this site — called "Yasniy," located in Siberia's southwestern corner — is fascinating, as I found out last June as a guest (and first-ever American journalist) of the company. Pinpointing the launch pad's exact location took some doing, and added to the fun.

As part of the conversion of retired military missiles for commercial purposes, a Russian company named Kosmotras contracted with the Russian Defense Ministry to buy surplus "Satan" missiles once their duty tours expired. At first, the missiles were trucked to Russia's main space base at Baykonur for launch, but then the rocketeers had a better idea — convert them, and launch them from their original duty station inside the nuclear missile base.

In accord with nuclear-arms reduction agreements, Russia released a map of the base and the locations of three-dozen underground silos with armed missiles. One of those pads has been decommissioned and converted to a launch site for the satellite mission; but nobody could divulge which one.

Because of the military security level in a region filled with thermonuclear weapons, my group was confined mostly to a 15-acre fenced compound. A razor-wire-topped chainlink fence and armed civilian guards surrounded us. We even had to watch the launch from there.

The launch pad was miles away from our hotel, barely visible on a western ridge from our rooftop location. A veteran of the previous launch pointed out its radio tower to me, and I took a compass reading to get the tower's azimuth.

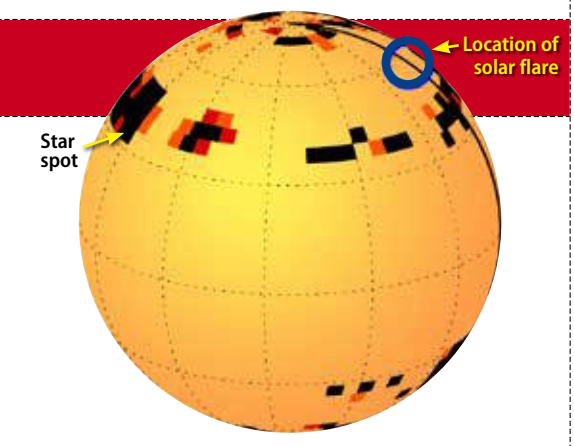
The following evening, we watched the launch from atop a bunker near the western fence. There was a flash as the booster rocket ignited, then silence as it climbed into the northwestern sky. I tape-recorded the crowd's shouts as the rocket first flared, and the rocket's roar when it hit us 32 seconds later.

THREE, TWO, ONE. A soviet "Satan" missile, like the one shown here, launched June 28, 2007, from Russia. The author watched the launch from the new Kosmotras satellite launch base at Yasniy, Siberia. USEC

The booster slowly faded into the high northern sky, while back to the west, the smoke plume from its launch drifted slowly to the left. I knew I could now figure out exactly where it was. But not yet — I hadn't brought the launch-pad maps with me, on purpose. (They weren't something I wanted to have to explain to my hosts during a security search.)

A week later, at home in Houston, I laid out the compound's geometry using a Google-Earth image, the true azimuth, and — thanks to the finite speed of sound — the launch pad's range. There it was: The pad designated "1-1," the base's oldest launch site, and quite reasonably, the one taken off military duty in order to make some money.

Seeing the launch was a thrill. Nailing down the exact lift-off location doubled my pleasure. And a few weeks later, watching the payload pass across Texas' skies completed the pattern. **— JAMES OBERG**



SOLAR FLARE. Doppler imaging mapped the location of cool, magnetically active "star spots" on the star BO Microscopii. The blue circle indicates the origin of a solar flare pinpointed by X-ray observations. ESO

Spots and flares mapped on Sun-like star

European and U.S. astronomers mapped solar flares on a Sun-like star's surface 150 light-years from Earth — a first. The European team achieved the observational feat by combining data from the European Southern Observatory's Very Large Telescope (VLT) and the European Space Agency's XMM-Newton X-ray satellite. The team also mapped cool, magnetically active spots on the star, BO Microscopii. The dark features are equivalent to our Sun's sunspots.

BO Microscopii is about 30 million years old and rotates rapidly — about 66 times faster than the Sun. The astronomers nicknamed BO Microscopii, located in the constellation Microscopium, "Speedy Mic." Studying stars like Speedy Mic could teach us something about the Sun's early era, says team member Uwe Wolter of the Hamburg Observatory in Germany.

A technique called Doppler imaging enabled the team to construct detailed maps of Speedy Mic's surface. Observers at the VLT collected 142 spectra as the star rotated. Each spectrum contained information about the star's surface from a slightly different point of view. Computer analysis then reconstructed the star's surface.

X-ray observations detected multiple solar flares, including one that lasted 4 hours. The VLT maps then pointed the way to the flares' exact points of origin.

Wolter is the lead author of a paper reporting the team's observations January 2008 in *Astronomy and Astrophysics*. **— D. P.**

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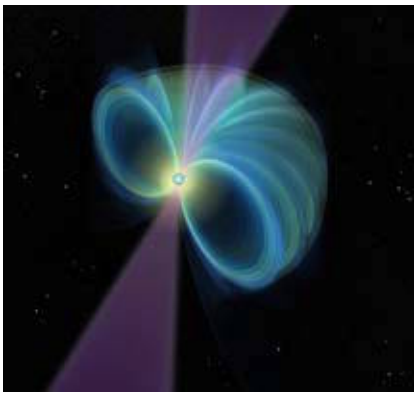

RUSSEL KIGHTLY MEDIA

TO CATCH A RRAT. Rotating radio transients (RRATs) are actually rotating neutron stars, scientists discovered.

Rotating radio star mystery solved

X-ray observations have revealed the true nature of strange, radio-emitting stars discovered in February 2006, a team of astronomers reported December 1 in *The Astrophysical Journal*. Using the XMM-Newton satellite, astronomers determined the "rotating radio transient" (RRAT) J1819–1458 harbors a neutron star spinning once every 4.26 seconds.

Observers had discovered 11 RRATs using Australia's Parkes Radio Telescope, but they appeared to emit only bursts of radio energy every 3 minutes or so, lasting only 3 milliseconds. The XMM-Newton observations confirm RRATs as rotating neutron stars.

Neutron stars are the cores of dead stars, 6 to 8 miles (10 to 12 km) wide, but containing as much mass as the Sun. As a neutron star spins, it emits a beam of focused energy, like a lighthouse beacon. From Earth, the energy looks like a periodic pulse.

The latest observations exposed a new mystery about RRAT's: As the X-ray energy leaves the star, something absorbs part of its spectrum. Astronomers think the obstruction is either gas around the star or the star's magnetic field.

Scientists know of only 21 RRATs, but their estimated number in the Milky Way is 100,000. **— D. P.**

Mars likely had water

Silicate-rich deposits found in martian soil suggest the Red Planet had a watery, habitable environment in its past.

NASA's Mars Exploration Rover Spirit upturned the silica while exploring near a plateau inside Gusev Crater known as Home Plate. The rover's mini-thermal emission spectrometer and alpha particle X-ray spectrometer showed the bright soil contains about 90 percent amorphous silica, a non-crystalline form of silicon oxide.

On Earth, hot water dissolves silica in rock below the water's surface. As cooled water rises, it causes the silica to precipitate out near the surface. Steve Squyres of Cornell University, principal investigator for NASA's Mars Exploration Rover mission, reported the discovery at the American Geophysical Union annual meeting in San Francisco in December. **— L. L.**

NASA

WATERY PAST. NASA's Spirit rover analyzed sandy soil from Mars' Home Plate feature in Gusev Crater and found silica that must have formed by precipitating out of water on the Red Planet.

BRIEFCASE

Squashed solar system

NASA's Voyager 2, after taking a different path than its twin, Voyager 1, confirms our solar system is "squashed." After crossing into the final frontier, the spacecraft found the bubble carved into interstellar space by the solar wind is not perfectly round. **— M. M.**

Subaru scope upgraded

The High Contrast Instrument for the Subaru Next Generation Adaptive Optics (HiCIAO) camera, installed on Hawaii's Subaru Telescope in December, will allow astronomers to block a star's direct light and search for nearby planets. **— L. L.**

Supernovae spawn dust

Astronomers using the Spitzer Space Telescope have detected 10,000 Earth-masses of dust in the Cassiopeia A supernova remnant. The finding, which appeared in *The Astrophysical Journal* January 20, confirms that massive exploding stars created the universe's first dust. **— L. L.**

25 years ago in *Astronomy*

April 1983

In 1983, astronomers were anticipating Voyager 2's arrival at Uranus and Neptune. Neither planet had yet been explored in detail, and many discoveries awaited.

"Voyager to Uranus and Neptune," in the April 1983 issue of *Astronomy*, predicted Voyager 2's arrival at these distant planets would answer many questions. "Even basic information such as their exact size and the length of their days remains in doubt," wrote authors Van R. Kane and Charles E. Kohlhase.

NASA's Voyager 2 spacecraft made its closest approach to Uranus January 24, 1986, and later arrived at Neptune August 25, 1989.

April 1998

10 years ago in *Astronomy*

Although scientists continue their search for life on other planets, one thing seems probable: Life will likely be found on a planet that resembles Earth.

In the April 1998 issue of *Astronomy*, "Wanted: Life-bearing planets" describes the search for an earthlike planet. Author Doug McInnis said the best way to find life is to look for the familiar: "carbon-based life in an oxygen atmosphere on small, warm, watery planets orbiting stars similar to our own general neighborhood."

Astronomers discovered the most earthlike exoplanet yet in April 2007. The exoplanet, located near parent star Gliese 876, has a radius only 50-percent larger than Earth's and may have water on its surface. **— MEGAN McCHAIN**

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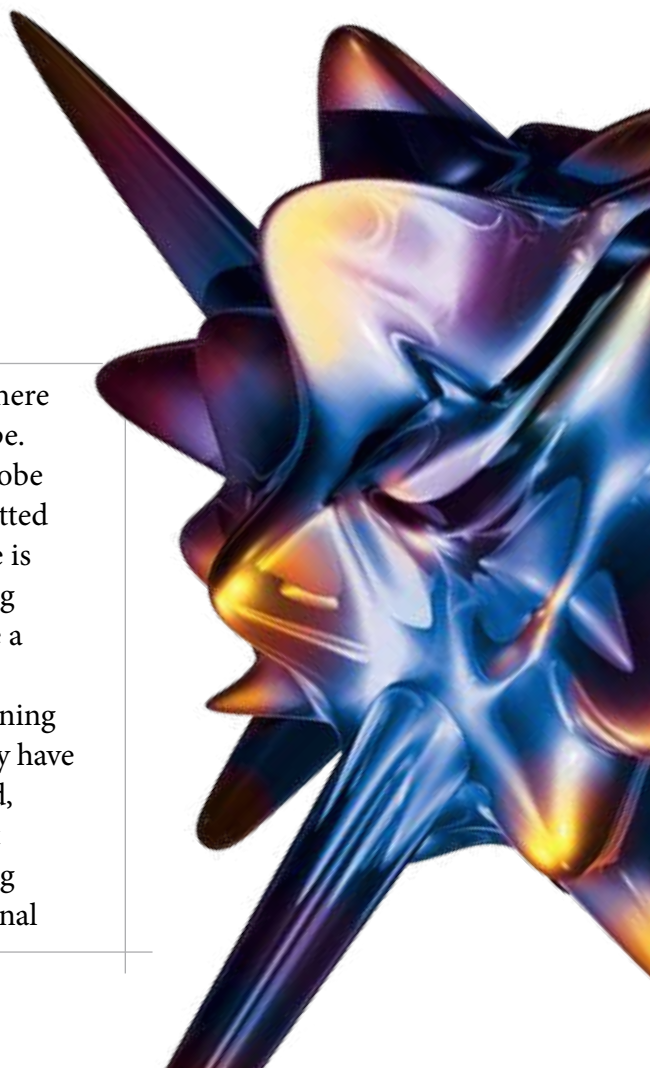
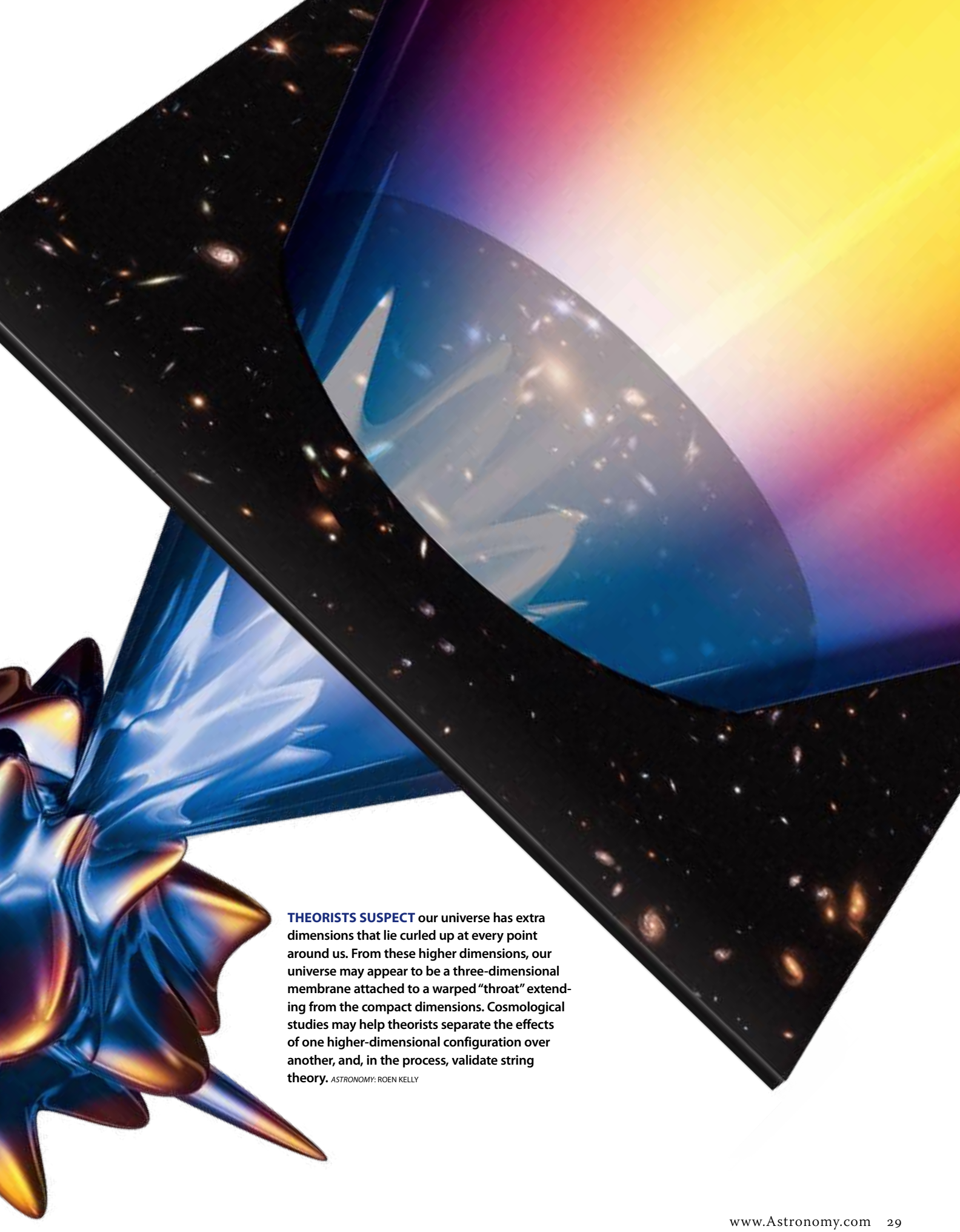
Searching for the shape of the universe

Inflation, an early period of cosmic hyper-expansion, may be the key to proving the universe has six extra dimensions. /// **BY STEVE NADIS**



For as long as people have studied the sky and wondered where it ends, or how, they've wondered about the universe's shape. Information from the Wilkinson Microwave Anisotropy Probe (WMAP), which is mapping the whisper of microwaves emitted 380,000 years after the universe's birth, indicates the universe is flat to within a 2-percent margin of error. If the universe is big enough, the cosmos could appear flat whether it's shaped like a pancake, a meatball, or a bagel.

But "outer space" — the seemingly immeasurable gulf containing billions of galaxies — isn't the only part of the universe that may have shape. Physicists say there's also an "inner space" — a concealed, microscopic realm tucked away so tightly we can't experience it directly. It's here that string theory, often regarded as our leading explanation of nature, postulates the presence of a 10-dimensional

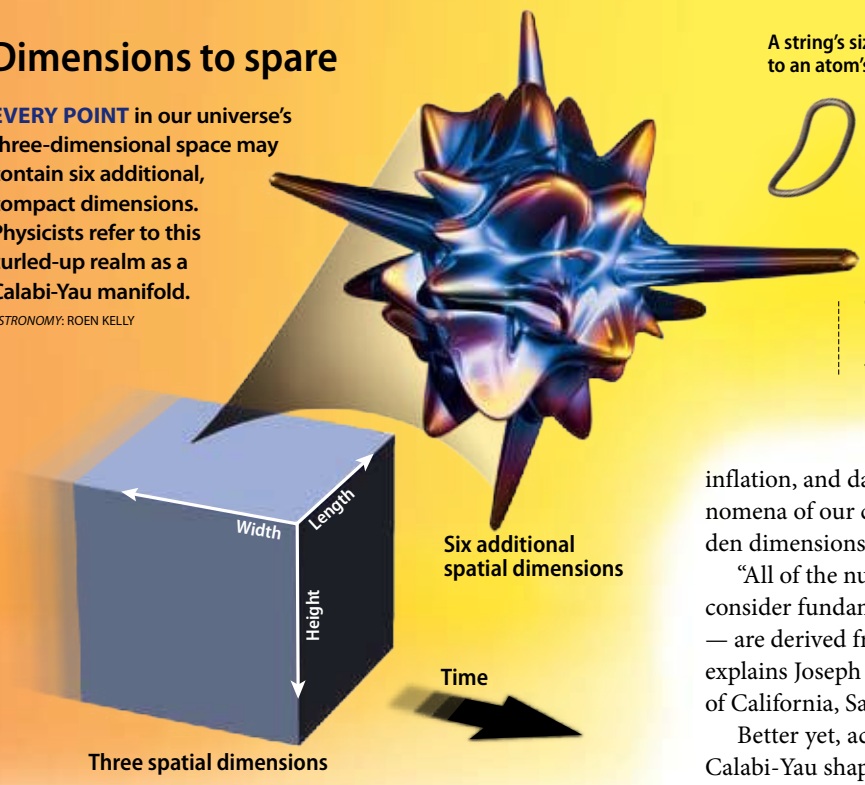


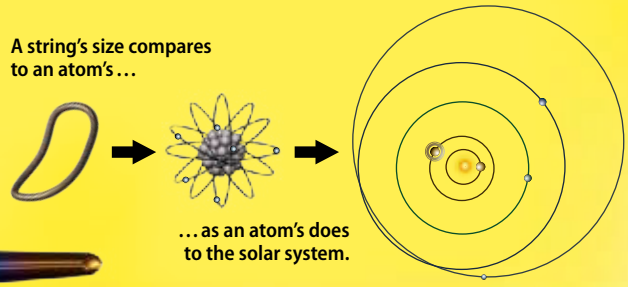
THEORISTS SUSPECT our universe has extra dimensions that lie curled up at every point around us. From these higher dimensions, our universe may appear to be a three-dimensional membrane attached to a warped "throat" extending from the compact dimensions. Cosmological studies may help theorists separate the effects of one higher-dimensional configuration over another, and, in the process, validate string theory. *ASTRONOMY*: ROEN KELLY

Dimensions to spare

EVERY POINT in our universe's three-dimensional space may contain six additional, compact dimensions. Physicists refer to this curled-up realm as a Calabi-Yau manifold.

ASTRONOMY: ROEN KELLY





THE TWISTED DIMENSIONS of Calabi-Yau manifolds may be similar in size to superstring theory's hypothetical strings. *ASTRONOMY*: ROEN KELLY

universe — the normal three dimensions of space we're familiar with, plus time, plus six other dimensions.

Six pack

Einstein's theory of general relativity unified space and time as a four-dimensional space-time a century ago, so where do string theory's extra dimensions reside? According to scientists, they're curled up into tiny geometrical containers called Calabi-Yau manifolds, where they remain forever hidden from us.

"If string theorists are right," says Harvard University physicist Lisa Randall, "everywhere in visible space — at the tip of your nose, at the north pole of Venus, at the spot above the tennis court where your racket hit the ball the last time you served — there would be a six-dimensional Calabi-Yau manifold of invisibly tiny size." This higher-dimensional geometry therefore exists at every point in space.

Physicists classify these intricate, twisted, geometric forms as compact —"something you can put in the trunk of your car," they often say. That's a bit of scientific understatement meant to convey that Calabi-Yau manifolds have no infinitely long structures. Their actual size remains an open question. Physicists initially regarded them as exceedingly small, with diameters on the order of the Planck scale (10^{-33} centimeters). Current thinking holds they're 10,000 trillion times larger than this, perhaps similar to the spatial scale of string theory's hypothesized strings — larger, perhaps, but still too small to detect.

Theorists are keenly interested in the shape of these complex, six-dimensional spaces. They believe the manifold's geometry dictates the laws of particle physics and influences gravity, cosmic inflation, and dark energy. If they're right, these dominant phenomena of our cosmos may either spring directly from these hidden dimensions or be profoundly affected by them.

"All of the numbers we measure in nature — all of the things we consider fundamental, such as the masses of quarks and electrons — are derived from the size and shape of Calabi-Yau space," explains Joseph Polchinksi, a theoretical physicist at the University of California, Santa Barbara.

Better yet, according to string theory, the number of possible Calabi-Yau shapes is linked to the number of possible universes — a "multiverse," as it's sometimes called. In fact, many of today's biggest problems in physics and cosmology reduce to a single geometry problem: determining the shape of extra dimensions.

So, what can we learn about inner space's geometry? Investigators have two main goals: to secure evidence for the existence of these dimensions, and obtain hints about their underlying geometry. The picture is still crude. Researchers have described these shapes, or parts of them, as ice cream cones, throats, cigars, gloves, and even anteaters.

"How are the extra dimensions of string theory curled up?" asks University of Wisconsin physicist Gary Shiu. He leads a team of researchers who think they've hit on a way to answer this question. "We argue that precise measurements of the cosmic microwave background [CMB] can give us clues," he says.

BRANES, STRINGS, AND THE CMB

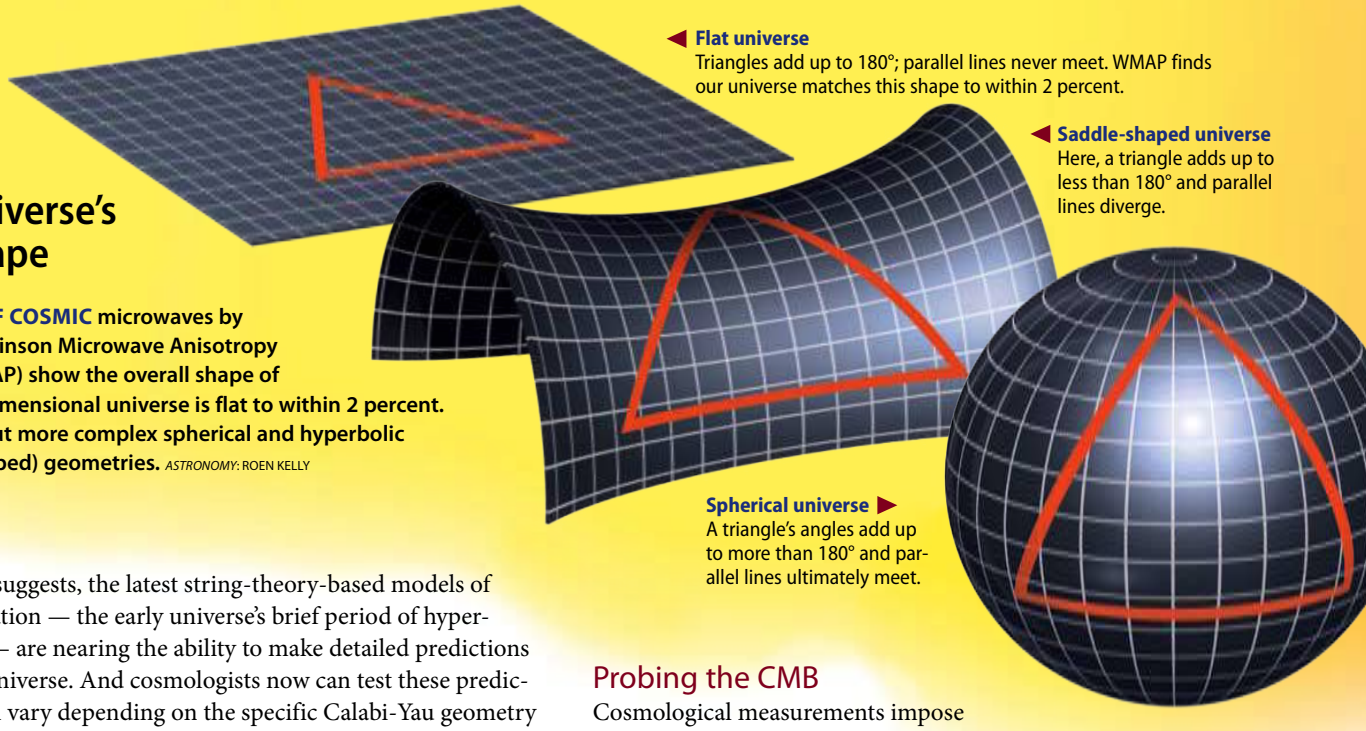
BRANE
Any of the extended objects that arise in string theory. A 1-brane is a string, a 2-brane is a membrane, and a 3-brane has three spatial dimensions.

COSMIC MICROWAVE BACKGROUND (CMB)
Microwave radiation suffusing the universe that was originally light produced 380,000 years after the Big Bang.

STANDARD MODEL
A theory of interactions of nature's most fundamental known particles (i.e., electrons and quarks) developed in the late 1960s and early 1970s. Its inability to explain gravity suggests a more fundamental theory exists.

STRING THEORY
A unified theory of the universe postulating that nature's fundamental ingredients are not particles but one-dimensional filaments called strings. String theory unites quantum mechanics and general relativity, which are otherwise incompatible; short for superstring theory.

Steve Nadis *is a contributing editor of* Astronomy. *He's working with Harvard University's Shing-Tung Yau on a book tentatively titled* The Shape of Inner Space.


Flat universe
Triangles add up to 180°; parallel lines never meet. WMAP finds our universe matches this shape to within 2 percent.
Saddle-shaped universe
Here, a triangle adds up to less than 180° and parallel lines diverge.
Spherical universe
A triangle's angles add up to more than 180° and parallel lines ultimately meet.

The universe's 3-D shape

STUDIES OF COSMIC microwaves by NASA'S Wilkinson Microwave Anisotropy Probe (WMAP) show the overall shape of our three-dimensional universe is flat to within 2 percent. This rules out more complex spherical and hyperbolic (saddle-shaped) geometries. *ASTRONOMY:* ROEN KELLY

As Shiu suggests, the latest string-theory-based models of cosmic inflation — the early universe's brief period of hyper-expansion — are nearing the ability to make detailed predictions about our universe. And cosmologists now can test these predictions, which vary depending on the specific Calabi-Yau geometry assumed responsible for inflation's birth, against CMB data.

Brane damage

The basic premise is that the motions and interactions of large, membrane-like structures called "branes" actually drove cosmic inflation. In this scenario, a brane and its opposite counterpart, an antibrane, slowly move toward each other in higher dimensions.

The two branes possess a mutual attraction, so their separation represents a vast source of potential energy — enough to trigger inflation. This fleeting process, which expanded our four-dimensional universe by more than a trillion trillion times, continued until the branes collided and annihilated each another. In this view, inflation occurs before the Big Bang. In fact, it's the energy released in the branes' mutual destruction that created and powered our Big Bang.

So the thing we've traditionally called our universe sits on a three-dimensional brane that would be a mere speck, or point, in a six-dimensional Calabi-Yau manifold. But how can our vast, and apparently infinite, cosmos fit into higher-dimensional space's ultracompact domain? Researchers say our three spatial dimensions are independent of the Calabi-Yau dimensions.

"Rather than pointing in the same direction, they point in orthogonal directions, so there's no trouble fitting in," explains Princeton University physicist Liam McAllister. Adds Henry Tye of Cornell University: "We're just sitting in a tiny corner of six-dimensional space."

The brane and antibrane responsible for inflation moved around in the early universe. "The fact that the branes have been moving allows us to learn much more about that space than just sitting in the corner," Tye says. "Just like at a cocktail party: You don't pick up much if you stay in one corner. But if you move around, you're bound to learn more." As it turns out, brane movement prior to inflation leaves an indelible imprint on the cosmic microwave background.

The dominant phenomena of our cosmos may spring directly from *hidden dimensions* or be profoundly affected by them.

Probing the CMB

Cosmological measurements impose constraints on the kind of Calabi-Yau space we live in. Observational data are now getting precise enough that researchers can determine whether a given Calabi-Yau manifold is consistent with experiment, a development physicists find encouraging.

"You can take inflation models and divide them in half — those that are favored by observations and those that are not," says physicist Cliff Burgess of Ontario's Perimeter Institute for Theoretical Physics. "The fact that we can now distinguish between inflation models means we can also distinguish between the geometric constructions that give rise to those models."

For example, a 2006 study led by Liam McAllister explored the observational signals of inflation occurring in an extended portion of a Calabi-Yau manifold called a "warped throat." The scientists found that different Calabi-Yau geometries lead to different observational signatures.

Ice cream cones and anteaters

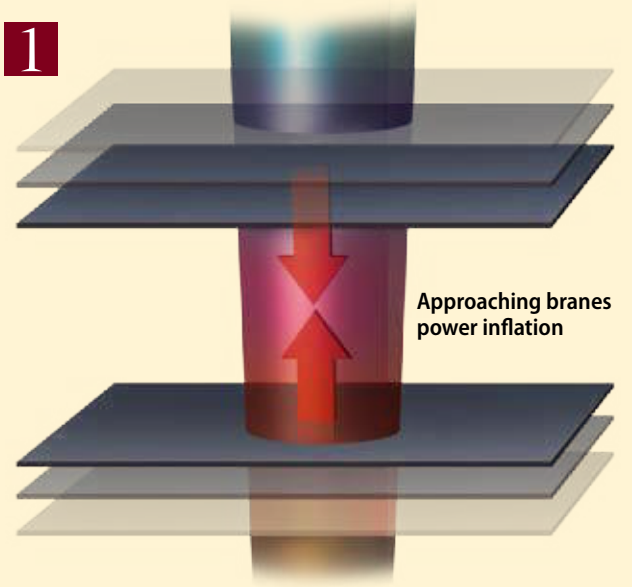
A "throat" is the most common defect found in Calabi-Yau space. It's a cone-shaped bump that naturally protrudes from the surface. McAllister suggests the image is reminiscent of a large scoop of ice cream — the bulk of those tightly wrapped dimensions — sitting atop a slender cone.

This throat becomes even more distended and warped by the magnetic fields, or fluxes, posited by string theory. "The flux exerts a force on the tip of the cone, stretching it out into a long, narrow neck like the snout of an anteater," explains Stanford University physicist Leonard Susskind.

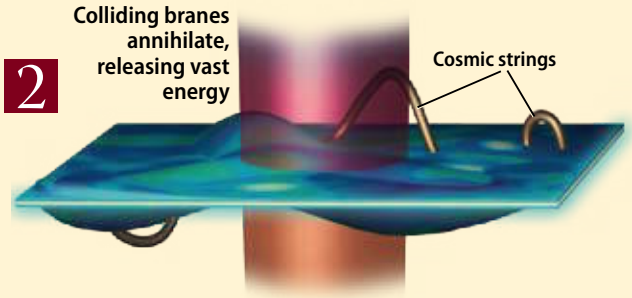
Any given Calabi-Yau space is likely to have more than one warped throat, so Cornell University astronomer Rachel Bean prefers the analogy of a rubber glove to that of an ice cream cone. "Our three-dimensional universe is like a dot moving down the finger of a glove," she explains. Inflation ends when the brane, or

Did annihilating branes trigger the Big Bang?

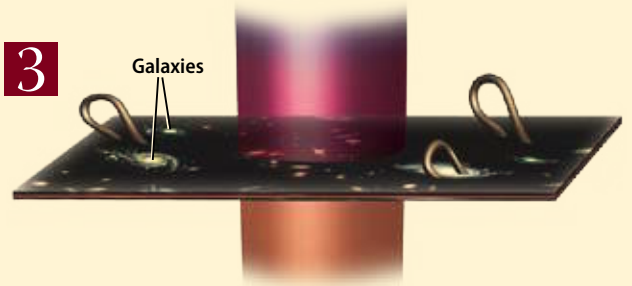
Physicists suggest a brane-antibrane pair interacted to create the Big Bang. Here's how it might have worked:



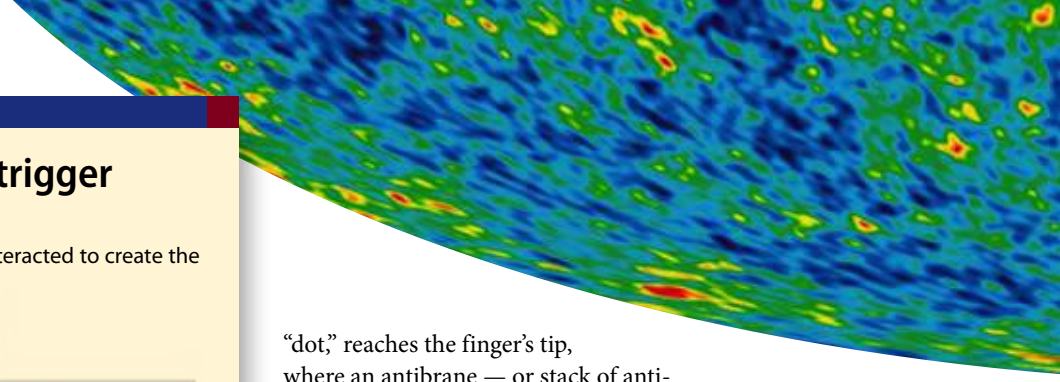
A brane and an anti-brane spanning our universe's three spatial dimensions move together. As they approach, inflation begins. The size of the universe grows a trillion trillion times and possibly creates ripples in space-time called gravitational waves.



Inflation ends when the branes collide and annihilate each another. The energy release heats up our universe, initiating the hot Big Bang. The collision may also create cosmic strings. Such structures may reveal themselves by gravitational lensing of distant background objects or by polarizing the CMB.



Density fluctuations produced during inflation become the seeds for today's cosmic structures. They also created the temperature fluctuations now being mapped in the CMB. *ASTRONOMY:* ROEN KELLY



"dot," reaches the finger's tip, where an antibrane — or stack of anti-branes — patiently waits. Because the finger's shape constrains the brane's motion, she says, the specific features of inflation stem from its geometry.

Suppose inflation occurred within the confines of two different warped-throat geometries. Could we tell them apart? Gary Shiu and his graduate student Bret Underwood looked at this question in a 2007 study. The scientists picked two relatively well-known throat models — named Klebanov-Strassler and Randall-Sundrum — and then looked at how inflation under these two different conditions would affect the CMB.

In particular, they focused on a standard CMB measurement: temperature fluctuations in the early universe. These fluctuations should appear roughly the same on small and large scales. Scientists call the rate at which these fluctuations change from small to large scales the "spectral index." Shiu and Underwood found a 1-percent spectral-index difference between the two scenarios. So, the choice of geometry has a measurable effect on that number.

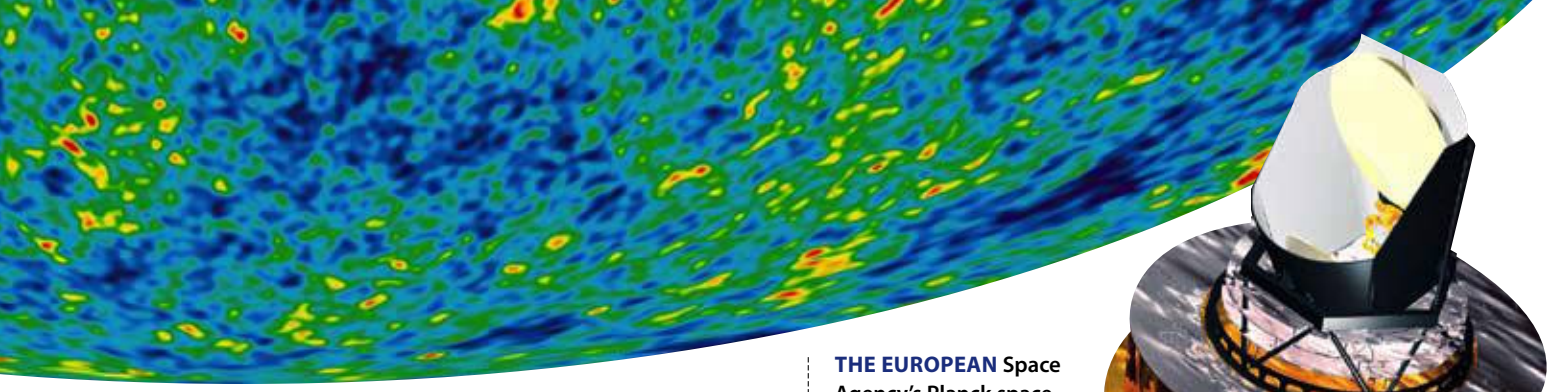
In cosmology, a 1-percent difference can be significant. The European Space Agency's planned Planck spacecraft, the next-generation CMB mapper scheduled for a July launch, could measure such differences. Planck data may allow one throat geometry as a possible shape for higher dimensions and eliminate another.

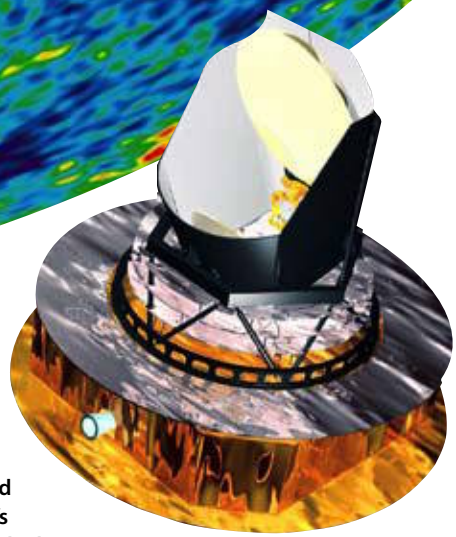
"Away from the tip, the two geometries look almost identical, and people used to think they could be used interchangeably," Underwood notes. "Shiu and I showed that the details do matter." Still, he admits that going from the spectral index, which is a single number, to the geometry of extra dimensions is a big leap.

If researchers have enough data on the CMB, can they determine what Calabi-Yau shape it is? Cliff Burgess doesn't think this will be possible in the next 2 decades. Liam McAllister also is skeptical. "We'll be lucky in the next decade just to be able to say inflation did or did not occur," he says. "I don't think we'll get enough experimental data to flush out the full shape of the Calabi-Yau space, though we might be able to learn what kind of throat it has or how many branes it has."

Shiu is more hopeful. "If you can only measure the spectral index, it's hard to say something definitive about the geometry," he says. But you'd get much more information if you could measure non-Gaussian features of the CMB — ways in which matter's clumpiness in the early universe deviates from a purely random distribution. A clear indication of this would impose more constraints on the underlying geometry. "Instead of one number, like the spectral index, it's a whole function — a whole bunch of numbers that are all related to each other," he adds.

If matter were particularly clumpy, it could point to a specific version of brane inflation known as Dirac-Born-Infeld (DBI) occurring within a well-defined throat geometry. "Depending on the precision of the experiment," Shiu says, "such a finding could, in fact, be definitive."





THE EUROPEAN Space Agency's Planck spacecraft (right) is slated for a July launch. Planck's high-resolution view of the cosmic microwave background is designed to best WMAP's (above). With enough detail, physicists could determine which possible Calabi-Yau geometries our universe cannot contain. TOP: NASA/WMAP SCIENCE TEAM; SPACECRAFT: ESA

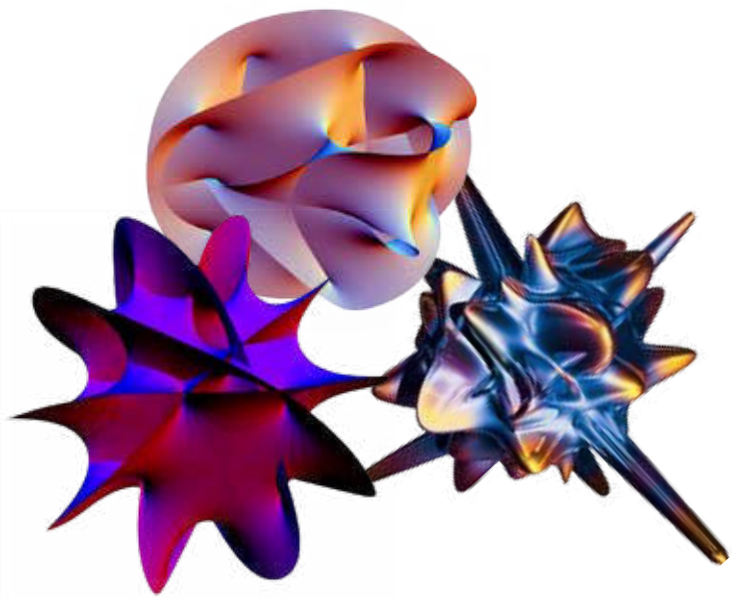
Columbia University physicist Sarah Shandera notes that a string-theory-motivated inflation model like DBI may prove important even if string theory fails as the ultimate description of nature. "It gives cosmologists something new to look for," she says. As in any experimental science, knowing what questions to ask, and how to frame them, is a big part of cosmology's game.

In the abstract realm of theoretical physics, warped throats are considered both fundamental and generic. They're features "that arise naturally from six-dimensional Calabi-Yau space," according to Princeton's Igor Klebanov. "No one can say how the universe works, yet I still think warped throats are a crucial part of the geometry of nature," he says. That belief may or may not be true, but warped throats offer theorists a setting rich in possibilities.

Strings across the cosmos

If inflation's driving force originated in a warped throat, then gravitational waves — ripples in the fabric of space-time — might bear clues about the specific manifold that generated them. Inflation should create such waves, but no one's detected them yet.

Hypothetical defects in space called cosmic strings, produced at the end of inflation, might yield even more telling signals. Cosmic strings are like the tiny strings of string theory, but they span the entire universe. Their presence would leave a distinct pattern in the cosmic microwave background. "The details of that signature would depend on the shape of the extra dimensions," Polchinski says.



CALABI-YAU MANIFOLDS wrap their extra dimensions in a variety of shapes. No one knows which geometry best describes our universe, but cosmology may help narrow down the possibilities.
TOP AND LEFT: ANDREW J. HANSON (INDIANA UNIV.); RIGHT: *ASTRONOMY*: ROEN KELLY

Warped-throat inflation models predict not just one cosmic string but a spectrum of them formed in brane-antibrane annihilations. The strings would have a range of tensions, similar to the properties of rubber bands of varying thicknesses. "Evidence of different types of cosmic strings would be a truly dramatic finding," Klebanov adds.

Getting a handle on the shape of Calabi-Yau space will require precise measurements of the CMB's spectral index, sightings of non-Gaussian clumping, and the detection of gravitational waves or cosmic strings. "Although we now have confidence in the standard model of physics, that model did not materialize overnight," Shiu notes. "It came from a whole sequence of experiments over the course of many years. In this case, we'll need to bring a lot of measurements together to get an idea of whether extra dimensions exist or whether string theory seems to be behind it all."

Patience, he says, is also in order, because researchers' overall goal is not just to probe the geometry of hidden dimensions. They also want to put to the test string theory itself, a branch of physics that has been criticized for lacking experimental support. The general strategy makes sense to Bret Underwood. He considers cosmology one of the most promising ways to test string theory because the energy scale of inflation is close to the energy scale needed to make strings.

"It's possible that string theory will predict a finite class of models, none of which are consistent with inflation," says Liam McAllister, "in which case we could say the theory is excluded by observation. Some models already have been excluded, which is exciting because it means the cutting-edge data really make a difference." At the moment, he says, warped-throat inflation is one of the best models produced so far, but, he cautions: "In reality, inflation may not occur in warped throats, even though the picture looks quite compelling."

In the end, the ultimate correctness of such models may not be their most important feature. "These models are based on geometries coming out of string theory for which we can make detailed predictions that we can then go out and test," says Rachel Bean. "In other words, they're a way of making a start."

WEB EXTRA Learn more about how the CMB tells scientists about hidden dimensions at www.Astronomy.com/toc.

185 million years before the dinosaurs' demise, did an asteroid nearly end life on Earth?

Scientists may have found the smoking gun. /// BY JOEL DAVIS

Some 250 million years ago, a biological catastrophe struck Earth. An estimated 75 percent of all land-living species and up to 95 percent of all ocean-dwelling species disappeared forever in a geologically brief pulse of mass extinction. And it probably occurred in less than 160,000 years — perhaps as little as 10,000 years. That is equivalent to less than a second if Earth's entire history were compressed into a single day.

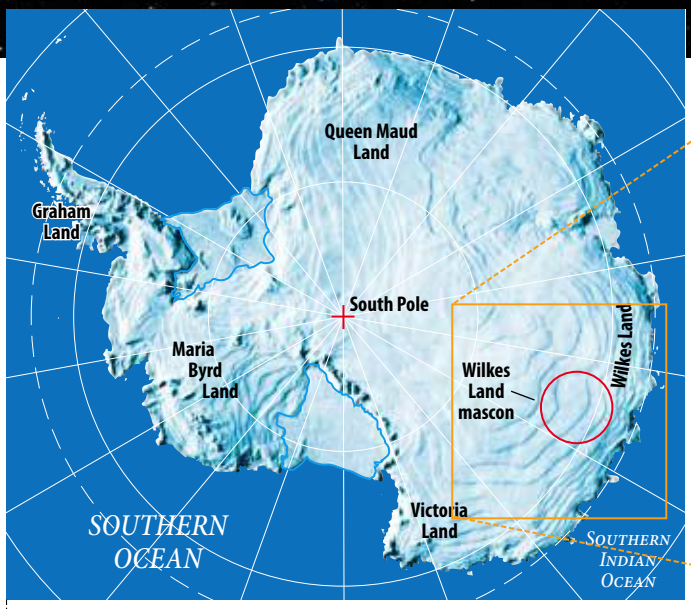
The mass extinction at the end of the Permian geological period was the worst such event Earth has ever endured. It was far worse than the better-known extinction 65 million years ago that ended the dinosaur era. Imagine that 99 out of every 100 people you know suddenly died. Now imagine that entire families of animals, not just individual species, suddenly disappeared: no more rabbits, no more bats, no more horses. The Great Dying, as some call the end-Permian extinction, was the biggest population crash in evolutionary history.

Scientists have long struggled to understand what virtually transformed Earth into a cemetery. The scenarios proposed so far include a global decline in seawater oxygen levels, greenhouse warming, and massive volcanic eruptions. Evidence has recently emerged for an entirely different kind of disaster that may have contributed to the Permian mass die off: a strike by a 30-mile-wide (50 kilometers) asteroid.

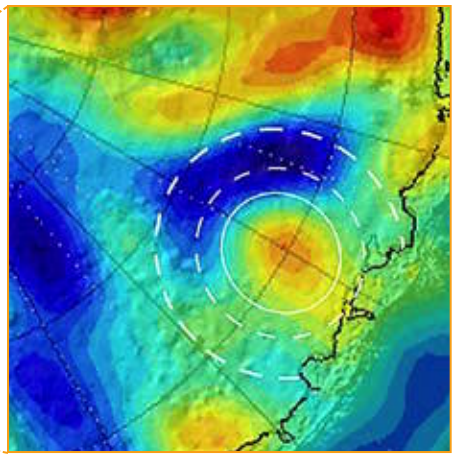
In 2006, Ohio State University geoscientist Ralph von Frese reported possible evidence of a geologic structure resembling an impact crater. The feature is buried in rock miles beneath the East Antarctic ice sheet. It lies below a region called Wilkes Land and may be more than 300 miles wide (500 km). If the feature is found

Joel Davis *is a writer in Sacramento, California. His most recent book is* Justice Waits: The UC Davis Sweetheart Murders *(Callister Press, 2005).*

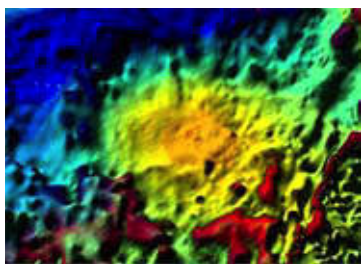
250 MILLION YEARS AGO, Earth's continents huddled in a single mass called Pangea. Some evidence suggests a meteorite strike at Pangea's southern tip contributed to a global extinction. LYNETTE COOK FOR *ASTRONOMY*



WILKES LAND, A DISTRICT OF ANTARCTICA, extends about a million square miles (2.6 million square kilometers) across the continent's glaciated surface. Gravity and radar studies have revealed the possible scar of an extraterrestrial impact beneath the ice, dating to a mass extinction 250 million years ago. *ASTRONOMY:* JAY SMITH



SCIENTISTS discovered a warp in the local gravity (solid circle) beneath the Antarctic ice. If the gravity anomaly is an ancient meteor crater, similar features on the Moon suggest the dashed circles would mark the location of multiple crustal ridges formed during the impact. RALPH VON FRESE (OHIO STATE UNIVERSITY)



COMBINING RADAR scans and gravity maps, Ohio State University researchers created an image of the suspected mass concentration in the rock beneath Antarctica. It resembles the impact scar from an asteroid or comet. RALPH VON FRESE (OHIO STATE UNIVERSITY)

to be an impact crater — and the evidence is very far from conclusive — it would be large enough to swallow Ohio.

Von Frese has no direct, physical evidence to prove the Antarctic feature is a crater. Nor does he have geological proof that it even dates to the end-Permian time. The evidence now consists only of a warp in the local gravity and surface topography.

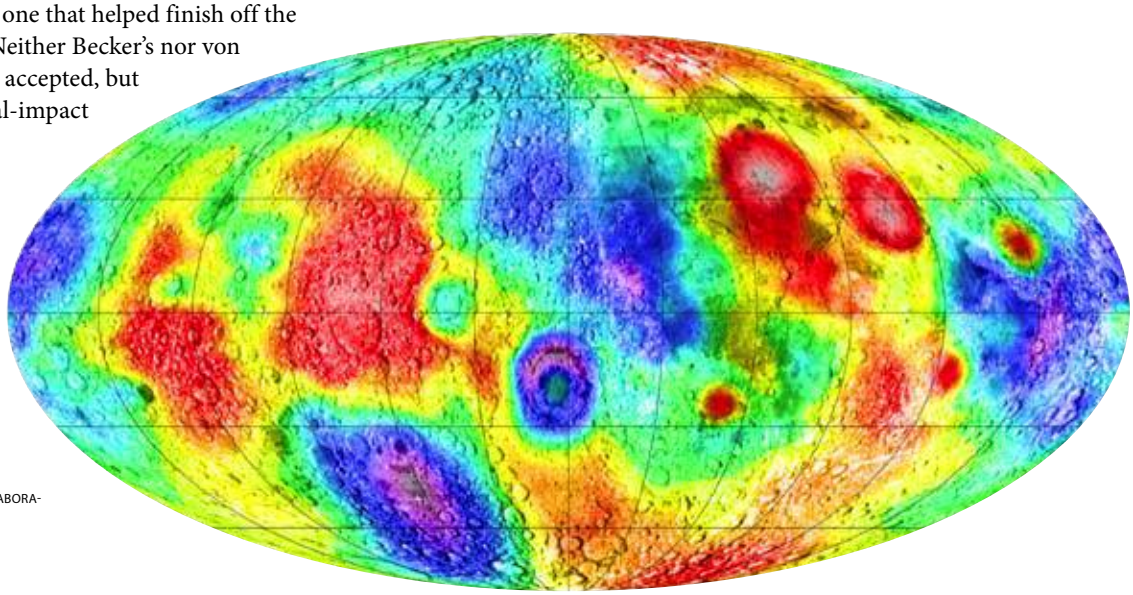
However, another team has reported much more substantial backing for a possible impact associated with the end-Permian extinction. It's a structure beneath the ocean floor 16 miles (25 km) off Australia's northwest coast called the Bedout ("Bedoo") High. The scientists, led by Johns Hopkins University geochemist Luann Becker, have marshaled multiple forms of evidence.

Becker and her colleagues say the data available are most consistent with a buried impact structure dating precisely to the end-Permian extinction. The impactor itself might have been a meteorite roughly the size of the one that helped finish off the dinosaurs 65 million years ago. Neither Becker's nor von Frese's scenario is yet universally accepted, but they have kept the extraterrestrial-impact hypothesis simmering.

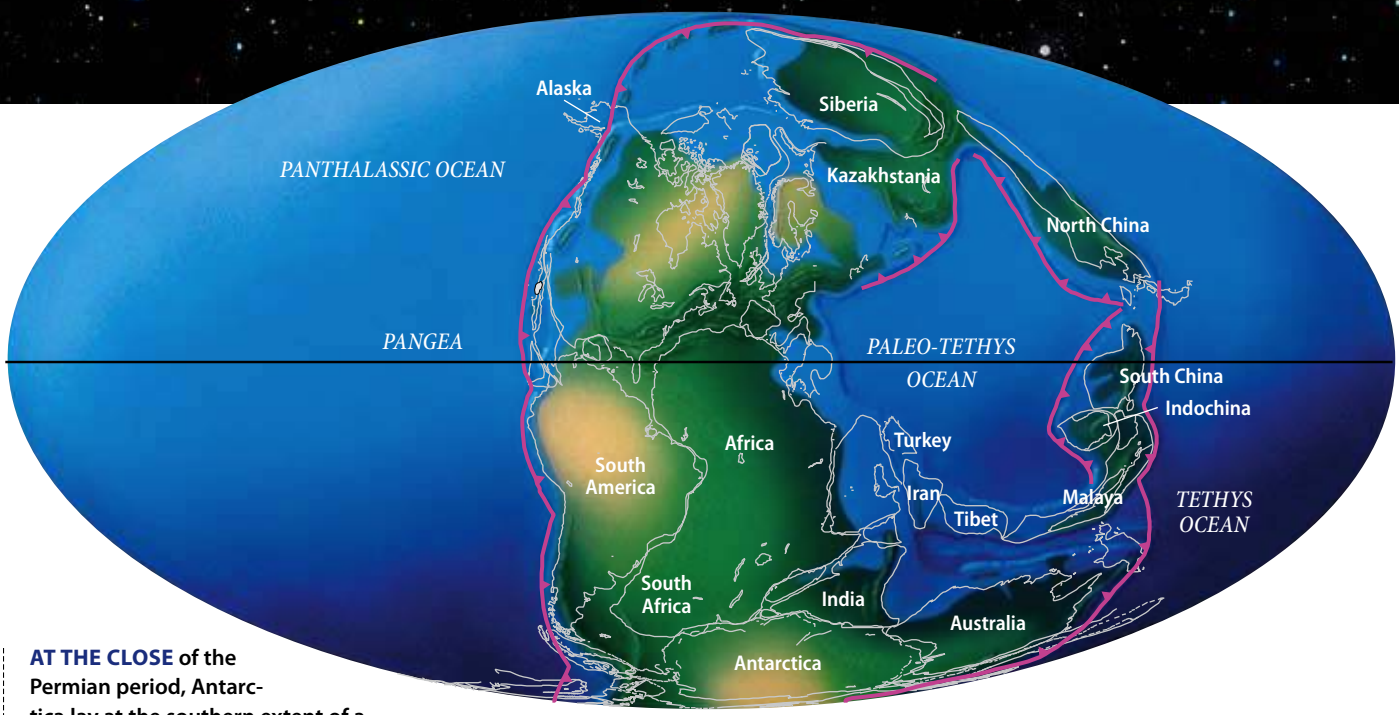
Mascon man

Von Frese found what he believes to be clues to Earth's "mother of all extinctions" by observing the Moon and planets. The information he commonly works with consists of gravity and magnetism measurements collected by satellites and space probes. He looks for concentration of mass, or "mascons" for short, in the lunar crust. Many mascons exist on the Moon.

Mascons can form when a meteorite smacks into the crust, causing molten rock to well up into the scar. The upwelled material is denser than the surrounding crust, creating a small increase in the local gravity. Spacecraft can detect the gravity boost as they pass over a mascon. Scientists, in turn, work backward from the



AS CLEMENTINE circled the Moon, slight dips in its orbit enabled scientists to map concentrations of mass in the crust below. These "mascons" increase the gravity above them, tugging on the spacecraft as it passes over. Such gravity anomalies often reveal buried features of the Moon's crust. PLANETARY GEODYNAMICS LABORATORY/NASA GODDARD SPACE FLIGHT CENTER



AT THE CLOSE of the Permian period, Antarctica lay at the southern extent of a "supercontinent" dubbed Pangea. Pangea's later breakup created the separate continents Antarctica and Australia. CHRISTOPHER SCOTESE/PALEOMAP PROJECT/WWW.SCOTESE.COM

size of the orbital blips to the variations in local gravity that caused them. Von Frese used this technique to map mascons on the Moon. His impact detector: the lunar-orbiting Clementine probe.

For the last several years, von Frese and his team have studied the sub-ice geology of Antarctica using data from NASA's twin Gravity Recovery and Climate Experiment (GRACE) satellites. The mission launched in 2002. Super-accurate gravity maps contain information about ocean currents, groundwater motions, glacial ice dynamics, and other processes of interest to environmental scientists. The team has used GRACE data to create something akin to a crude X ray of what lies beneath the Antarctic ice.

Lunar insights

A newspaper report von Frese saw in 2004 provided the original impetus to seek mascons in Antarctica. The article discussed the possibility that a meteorite strike caused the end-Permian extinction. Similarly, a geologic structure known as Chicxulub crater, buried beneath the northern edge of Mexico's Yucatán Peninsula, marks the location of the impact linked to the dinosaur's decline about 65 million years ago.

The much more severe end-Permian extinction happened 185 million years earlier. Since then, shifts in Earth's dynamic crust have erased most Permian crustal geology — but not all.

"When we looked for it, it just jumped out at us," von Frese recalls. "It's similar to what is seen for mascons on the Moon and Mars. Sometimes it's called a sombrero anomaly."

The Wilkes Land mascon lies nearly centered below a shallow circular pattern previously mapped with ice-penetrating radar. It reminded von Frese of a lunar mascon. Similar structures exist on Mars, Venus, and Mercury. Most of them are geologically "dead." Their interiors cooled long ago into rock, "freezing" the mascons in place. Even the most ancient mascons remain visible on geologically inactive moons and planets.

Earth's eraser

Earth is different. The mantle below our planet's relatively thin crust remains hot and plastic. Over millions of years, the mantle flows. These motions gradually obscure mascons.

Earth's active surface quickly erases surface craters. "We've seen nothing else yet in the satellite data," von Frese says. "We've looked at other big impact craters, like Vredefort in South Africa, but we don't see anything."

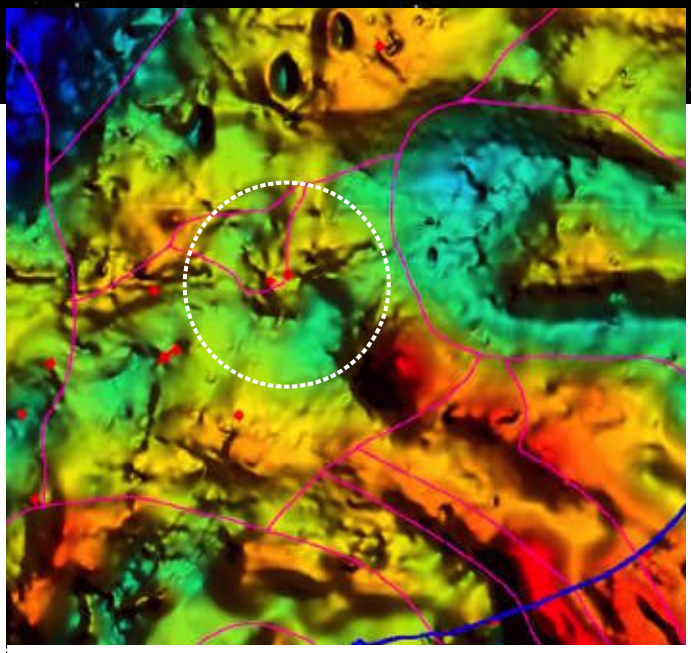
"WHEN WE looked for it, it just jumped out at us." — *Ralph von Frese*

The Vredefort Structure is the highly eroded remnant of a crater about 190 miles (300 km) across and more than 2 billion years old. On the Moon, a crater as large as Vredefort would still have a mascon. Vredefort has none.

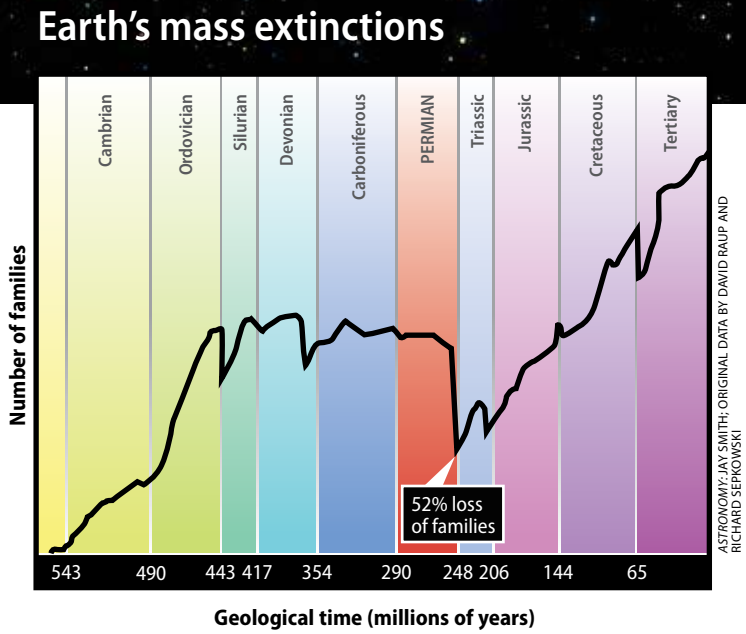
The Antarctic mascon's very existence suggests to von Frese that the Wilkes Land gravity anomaly is much younger than the Vredefort structure. He roughly estimates it to be less than 1 billion years old, although this is just an educated guess. In another half a billion years, he says, the Wilkes Land anomaly — whatever it is — will disappear.

Von Frese's mascon hypothesis remains on shaky scientific ground. What he needs to prove his case are actual rocks with geological or geochemical evidence of an extraterrestrial impact and its age. But physical proof will be hard to come by in a remote environment like Wilkes Land.

Von Frese had originally hoped to find new evidence in rocks dumped by the Wilkes Land ice sheet as it slides off the continent



UNDER THE OCEAN FLOOR northwest of Australia, a buried geological structure (dashed circle) harbors fractured and melted minerals. This represents evidence for a possible cataclysmic impact near the end of the Permian. LUANN BECKER (JOHNS HOPKINS UNIVERSITY)



FIVE TIMES IN EARTH'S HISTORY, mass extinctions pruned the tree of life. The Late Cretaceous extinction took the dinosaurs, but a far more severe die-off occurred in the Late Permian Period. It, too, may be linked to an impact by a comet or asteroid.

into the Southern Ocean. On a trip to Tasmania's capital city, Hobart, von Frese's hopes were dashed.

"I looked at maps of the edges of Wilkes Land and saw it's 200 feet of ice straight down into the sea," von Frese says. "Also, no one knows if the ice sheet is a warm or cold glacier. A warm glacier has a slush layer at its bottom and it picks up stuff from the rock bed as it flows forward. A cold glacier doesn't do that."

That leaves two options. One is to drill through the ice sheet into the anomaly, a difficult and expensive prospect in a place like Antarctica. "There's also been talk of using a submarine to go under the ice shelf to gather rock samples, because the edges are floating on the sea," he adds, "but that's as far-fetched as drilling."

Von Frese thinks additional evidence could come from more gravity and magnetic mapping. But such fresh data will still need backing from physical evidence — samples of a meteorite, for example, and examples of typical features that form in rock struck by an impactor.

DID A ROCK from outer space contribute to the most profound evolutionary shift in Earth's history?

A bigger bang

The impactor that formed Chicxulub was an estimated 6 miles (10 km) across. Creating a crater the size of the Wilkes Land gravity anomaly would require an object at least 30 miles (50 km) across — about the size of the Hawaiian island of Kauai.

If such an object did strike Earth, it would have rung the planet's crust like a giant bell. Enormous earthquakes would have rocked vast areas. The impact site's antipode — the exact opposite side of the globe — may have experienced a devastating "focusing" of seismic energy. The shaking might have exacerbated eruptions probably already in progress.

The Siberian Traps, ancient lava flows covering 4 million square kilometers and also dating to the end-Permian extinction, would have been near the Antarctic antipode about 250 million years ago. The environmental effects of this sustained volcanism, combined with a major meteorite impact, could have been catastrophic, and what made the end-Permian mass extinction a truly global phenomenon.

Other suspects

To date, however, the evidence much favors the Bedout High over the Wilkes Land anomaly as an end-Permian impact scar. Becker's team proposes that the Bedout High is actually the central uplift of an impact crater some 125 miles (200 km) wide, and buried under about 2 miles (3.2 km) of sediment younger than the Permian period. The Bedout High could be the top of a sombrero-like structure of the type sometimes associated with impact craters.

Since 2001, Becker and her colleagues have reported different kinds of data to support their interpretation of the Bedout High. For example, rock samples recovered from Bedout during offshore oil exploration contains physical evidence of an extraterrestrial origin for the structure. This includes minerals formed under sudden and extreme temperatures and pressures like those generated only by an impact. Such forces are large and sudden enough to transform crystalline minerals into amorphous glass without changing their outward shape.

Also, Becker collected rock samples in Antarctica that appear to contain meteorite fragments from the reputed impact off the Australian coast. And isotope dating places the Bedout High and

UNIVERSITY OF MICHIGAN EXHIBIT MUSEUM OF NATURAL HISTORY

THE PERMIAN GARDEN

LIFE DURING THE PERMIAN PERIOD was diverse and populous. Most species visible in this museum diorama of a Permian reef perished in a global mass extinction.

At the beginning of the Cambrian geologic period, 543 million years ago, life on Earth mushroomed into a huge variety of families, genera, and species. An eons-long greenhouse effect followed the Cambrian, and there's evidence the atmosphere had a higher percentage of oxygen than now.

By the beginning of the Permian period, about 290 million years ago, global temperatures had moderated and atmospheric oxygen had dropped to levels more like today's. Earth's crustal plates had slammed together into another supercontinent dubbed Pangea. It stretched like a fat crescent from the North to the South poles.

The ancestral families of many of today's terrestrial animal species made their first appearances in the Permian. The skies swarmed with flying insects. Forests with a rich mixture of holdover Carboniferous species as well as ginkgos, cycads, and newly evolved conifers spread across many of Pangaea's coastal and near-interior regions. Ammonoids (the distant ancestors of today's pearly nautilus) flourished in the seas, as did many species of mollusks, echinoderms (like today's sea urchins and starfish), and brachiopods, also known as lamp shells from their shape.

Then sometime approximately 250 million years ago, the Permian good times came to a disastrous end. — *J. D.*

its minerals right at the end-Permian time — 250.1 million years ago, plus or minus an error of 4.5 million years.

In 2006, Becker and her colleagues reported additional evidence for their hypothesis at the Lunar and Planetary Science Conference. In rock samples from Bedout, they found unusual isotopes of chromium that also point to an extraterrestrial origin. In short, the rocks appear to have come from space.

The scientists think they have made a compelling case, but it remains controversial. Other scientists have pecked away at various pieces of evidence. Some propose that the Bedout High is actually the remains of an ancient volcano. Becker's colleague Craig Nicholson of the University of California in Santa Barbara flatly rejects that idea.

"What explanation is least astonishing?" he says. "If it is a volcano, then it was at least 40 to 60 kilometers in diameter and 7 kilometers high. There's no other volcano in the world that looks like that." Nor does the mineralogical and geochemical evidence jibe with a volcanic origin, he adds.

Another group of geoscientists from Australia and Norway have argued the Bedout High is an entirely geological structure. They reviewed data from seismic studies and measurements of the crustal temperature in deep boreholes. Their conclusion: The unusually hot mantle caused rifting (spreading) in the crust at Bedout before and after the Permian, creating a high spot.

Nicholson, however, counters that the study ignores the fact that several independent measurements put the Bedout's age right at the end of the Permian. The debate will undoubtedly continue.

A fresh start

The Great Dying did more than kill most species on Earth. By wiping the biological slate nearly clean, it also gave life a fresh start. The surviving species were the distant ancestors of all life on Earth today. They all flowered from the remnants of the Great Dying — and perhaps the rubble of a giant extraterrestrial impact. If so, then we'll have to get used to the somewhat unsettling idea that the most profound evolutionary shift in Earth's history resulted from a chance collision with a rock from outer space.

WEB EXTRA To learn more about the possible causes of the great Permian extinction, go to www.Astronomy.com/toc.

BY MARTIN RATCLIFFE AND ALISTER LING

APRIL 08

The Moon grazes the Pleiades

A CRESCENT MOON met the Pleiades star cluster March 22, 2007. The two meet again after sunset April 8, although the Moon will be a thinner crescent then. RICHARD McCOY

Shortly after sunset April 8, the waxing crescent Moon crosses the bright Pleiades star cluster. This spectacular evening occultation highlights a month featuring several worthy solar system targets. Both Mars and Saturn grace the evening sky. The Red Planet shines brightly in Gemini, while the ringed planet

plies Leo and remains visible until shortly before dawn. In the early morning, nice views of Jupiter will be punctuated by fleeting streaks of light from the Lyrid meteor shower around April 22.

Mars appears conspicuous among the background stars of Gemini the Twins. The 1st-magnitude planet begins April just 1° east of Epsilon (ε) Geminorum. It then cuts diagonally across the constellation, pairing briefly with the waxing crescent Moon the evening of April 11. Mars passes 5° south of the equally bright star Pollux April 28, before closing the month almost in line with Castor and Pollux. For a week or so, Gemini morphs from twins into triplets.

Unfortunately, viewing Mars through a telescope can't compete with its naked-eye splendor. The planet's growing distance from Earth reduces its apparent size to a lackluster 6". You'll need a medium-sized scope to see much detail on the tiny gibbous disk.

Mars' evening companion, **Saturn**, shines brightly at magnitude 0.4. It appears 2.5 times brighter than Regulus, Leo the Lion's brightest star, which lies a bit more than 2° west of Saturn. Although winter's brilliant stars still dominate the sky's western half, the ringed planet stands as the brightest jewel in the southern sky. By April's end, Saturn lies due south and at its highest point as twilight falls. A gibbous Moon lies beneath Saturn April 15.

Saturn's telescopic appearance will change significantly during the next 2 years. Twice

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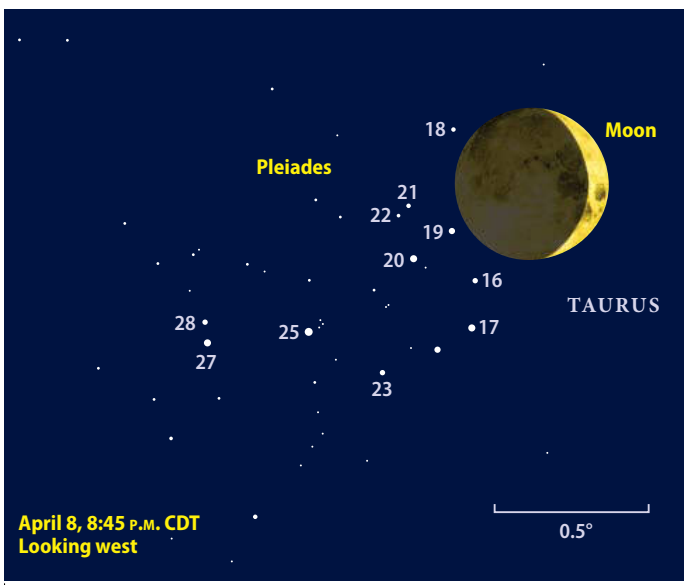
Visible to the naked eye
Visible with binoculars
Visible with a telescope

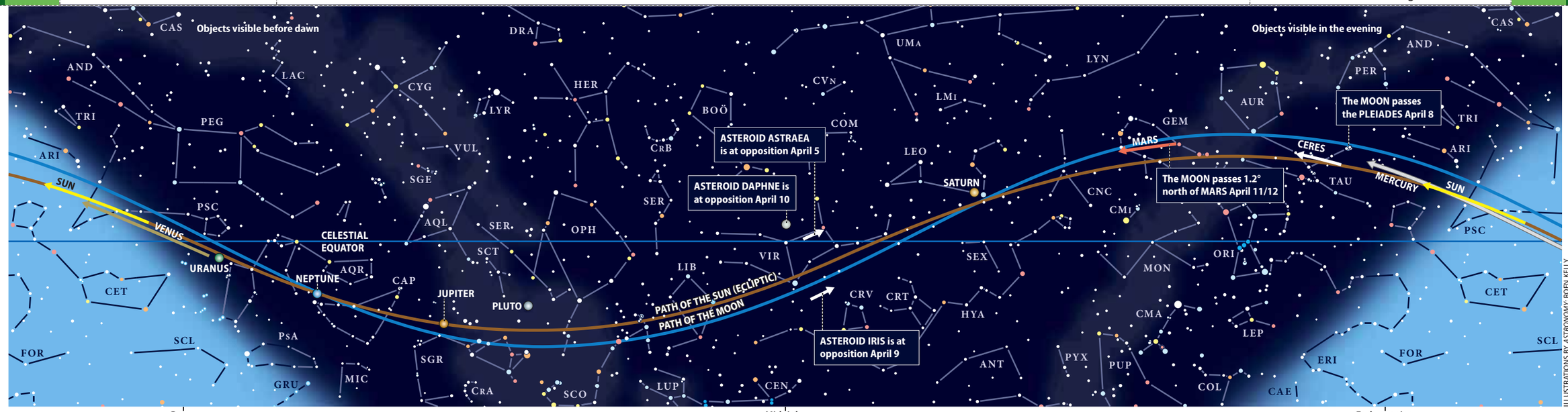


WATCH THE MOON snuff out individual stars in the northern Pleiades April 8. This illustration depicts the scene just before the stellar occultations begin. *ASTRONOMY:* JAY SMITH

Planets in April

This map unfolds the entire night sky from sunset (at right) until sunrise (at left). Arrows and colored dots show motions and locations of solar system objects during the month.

Astronomy magazine



ILLUSTRATIONS BY *ASTRONOMY*: ROEN KELLY

To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.

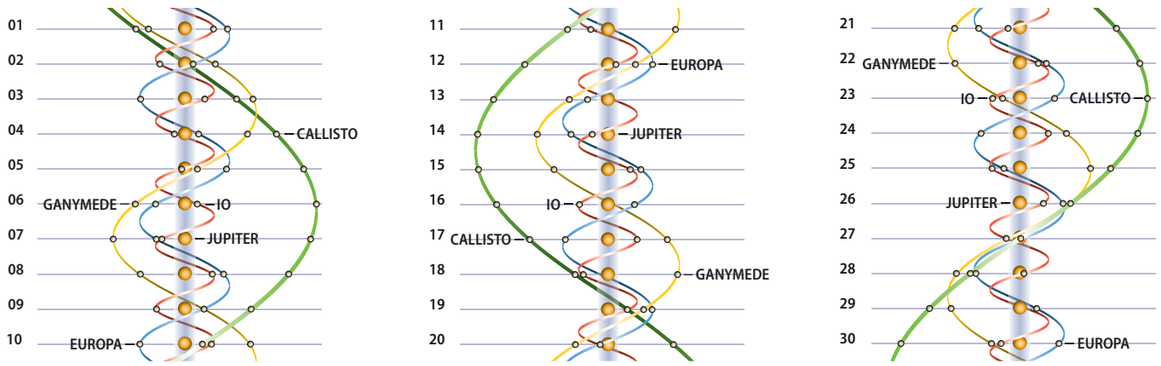
PLANETS	MERCURY	MERCURY	VENUS	MARS	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
Date	April 1	April 30	April 15	April 15	April 15	April 15	April 15	April 15	April 15
Magnitude	−0.6	−1.0	−3.8	1.0	−2.2	0.4	5.9	7.9	13.9
Angular size	5.2"	5.8"	10.1"	6.4"	39.1"	19.2"	3.4"	2.2"	0.1"
Illumination	89%	78%	97%	90%	99%	100%	100%	100%	100%
Distance (AU) from Earth	1.288	1.152	1.652	1.475	5.043	8.662	20.913	30.504	31.023
Distance (AU) from Sun	0.412	0.316	0.727	1.662	5.209	9.294	20.097	30.040	31.446
Right ascension (2000.0)	23h51.7m	3h28.0m	0h41.7m	7h15.5m	19h32.2m	10h18.1m	23h26.5m	21h44.4m	18h04.1m
Declination (2000.0)	−3°20'	20°36'	2°52'	24°24'	−21°45'	12°31'	−4°25'	−13°55'	−17°03'

10"

S W E N

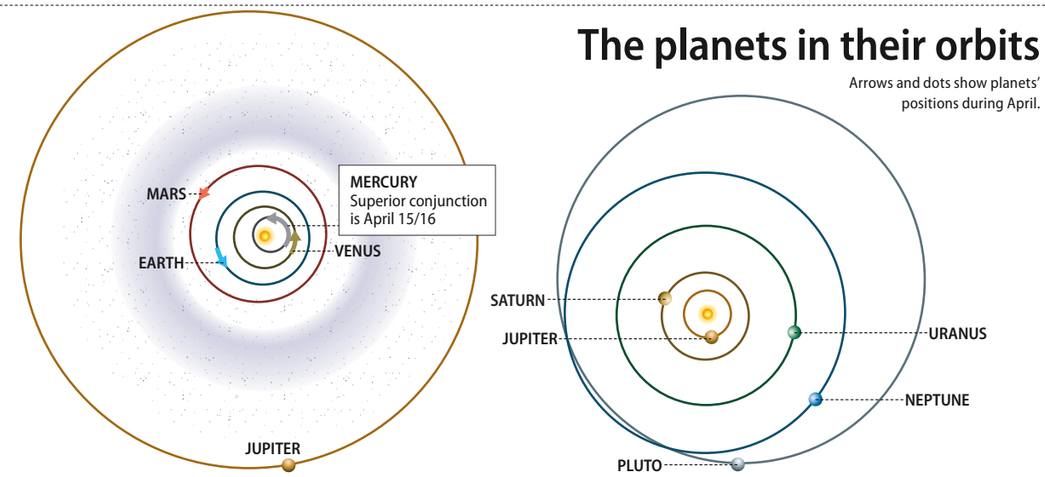
Jupiter's moons

Dots display positions of Galilean satellites at 5 A.M. EDT on date shown. South is at top to match the view through a telescope.



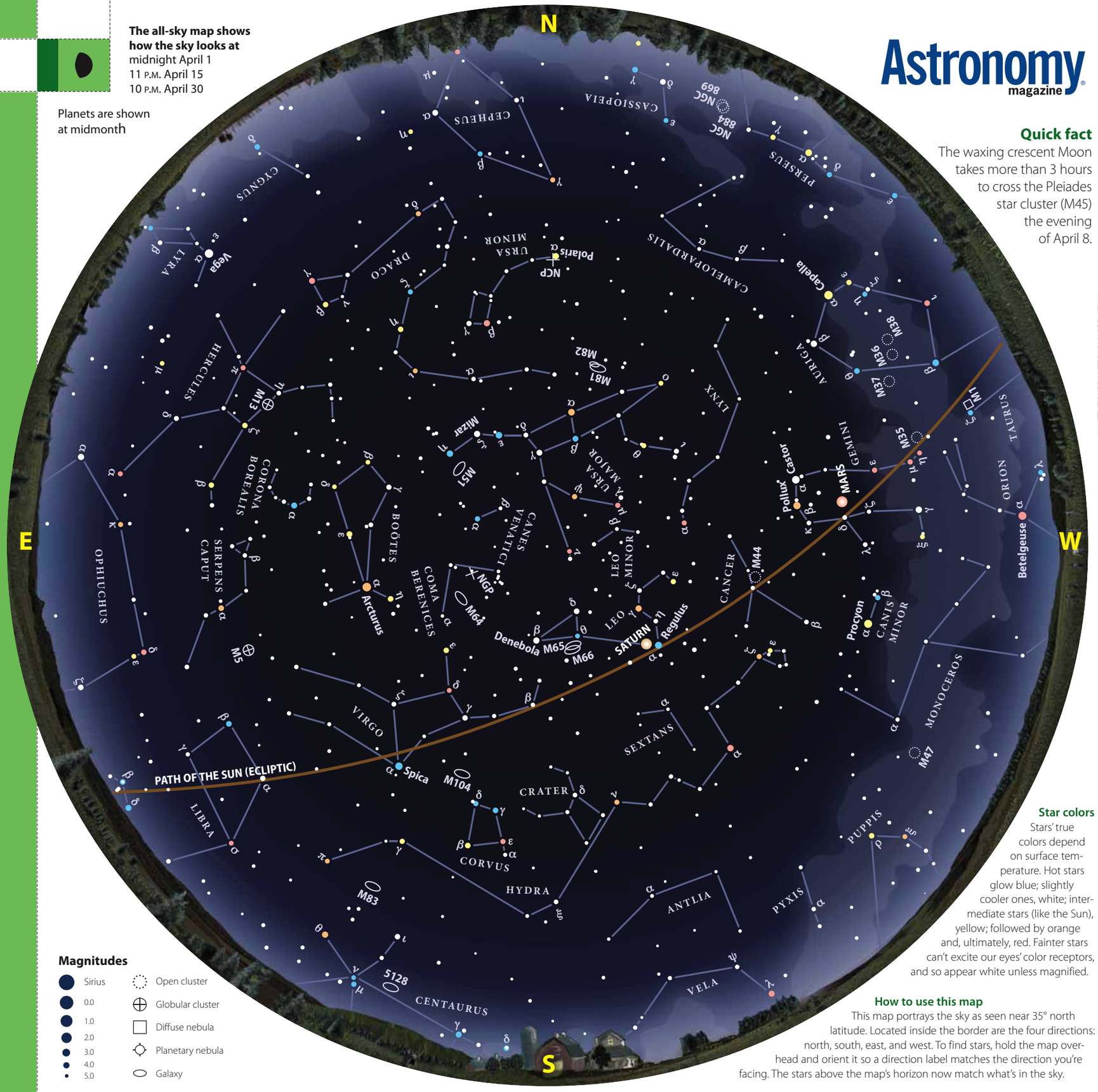
The planets in their orbits

Arrows and dots show planets' positions during April.



The all-sky map shows how the sky looks at
midnight April 1
11 P.M. April 15
10 P.M. April 30

Planets are shown at midmonth



Magnitudes

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0
- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

Star colors
Stars' true colors depend on surface temperature. Hot stars glow blue; slightly cooler ones, white; intermediate stars (like the Sun), yellow; followed by orange and, ultimately, red. Fainter stars can't excite our eyes' color receptors, and so appear white unless magnified.

How to use this map
This map portrays the sky as seen near 35° north latitude. Located inside the border are the four directions: north, south, east, and west. To find stars, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

Astronomy magazine

Quick fact
The waxing crescent Moon takes more than 3 hours to cross the Pleiades star cluster (M45) the evening of April 8.

NOTABLE OBSERVING DATE:
April 8, when the Moon passes through the Pleiades star cluster

april 08

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
		[01]	[02]	[03]	[04]	[05]
[06]	[07]	[08]	[09]	[10]	[11]	[12]
[13]	[14]	[15]	[16]	[17]	[18]	[19]
[20]	[21]	[22]	[23]	[24]	[25]	[26]
[27]	[28]	[29]	[30]			

ILLUSTRATIONS BY *ASTRONOMY*: ROEN KELLY

02 The Moon passes 0.002° north of Neptune, 5 A.M. EDT

04 The Moon passes 3° north of Uranus, 6 A.M. EDT

The Moon passes 5° north of Venus, 9 P.M. EDT

05 Asteroid Astraea is at opposition, 8 P.M. EDT

New Moon occurs at 11:55 P.M. EDT

07 The Moon is at perigee (224,365 miles from Earth), 3:30 P.M. EDT

08 **The Moon passes through the Pleiades star cluster**

09 Asteroid Iris is at opposition, 5 A.M. EDT

10 Asteroid Daphne is at opposition, 5 P.M. EDT

12 The Moon passes 1.2° north of Mars, 2 A.M. EDT

First Quarter Moon occurs at 2:32 P.M. EDT

15 The Moon passes 0.9° south of Regulus, 10 A.M. EDT

The Moon passes 3° south of Saturn, 2 P.M. EDT

16 Mercury is in superior conjunction, 3 A.M. EDT

20 Full Moon occurs at 6:25 A.M. EDT

22 Lyrid meteor shower peaks

23 The Moon is at apogee (252,241 miles from Earth), 5:34 A.M. EDT

The Moon passes 0.3° south of Antares, 1 P.M. EDT

27 The Moon passes 3° south of Jupiter, 1 A.M. EDT

28 Last Quarter Moon occurs at 10:12 A.M. EDT

Mars passes 5° south of Pollux, 4 P.M. EDT

WEB EXTRA For definitions of terms, visit www.Astronomy.com/glossary.

— *Continued from page 40*

during Saturn's 29.5-year orbit around the Sun, the planet's ring system tilts edge-on to our view from Earth. This geometry renders the gossamer-thin rings all but invisible. The clock is ticking: The rings will disappear for most observers in late 2008 and much of 2009. This month, however, the 44"-diameter rings stay gorgeous. You'll easily see the dark Cassini Division on the rings' eastern and western sides.

The rings' narrow tilt reveals most of Saturn's disk, which spans 19". During moments of steady seeing, you should see subtle atmospheric features. Also look for the planet's increasingly obvious shadow as it falls on the rings' far side east of the globe.

Martin Ratcliffe *is the author of* State of the Universe 2008 *(Praxis, 2007).* **Alister Ling** *is a meteorologist for Environment Canada.*

Several moons circle Saturn like lazy fireflies, creating a panorama that changes night to night. Easy to see in any telescope is Titan, an 8th-magnitude object that handily outshines the other moons. It passes due south of Saturn April 2 and 18 and due north April 10 and 26.

A 4-inch scope gathers enough light to pull in a trio of 10th-magnitude moons: Rhea, Tethys, and Dione. Two-toned Iapetus glows a magnitude fainter when it passes due north of Saturn April 28. An 8-inch scope combined with good seeing and a favorable elongation usually brings 12th-magnitude Enceladus into view.

As Saturn dips low in the west during the early morning hours, **Jupiter** climbs in the southeast. The giant planet rises around 3 A.M. local daylight time April 1, and 2 hours earlier by month's end. Shining at magnitude –2.2, Jupiter is the

LYRID METEORS will streak the sky before dawn April 22, although a bright gibbous Moon will drown out the shower's fainter meteors. *ASTRONOMY:* JAY SMITH

A TALE OF TWO STREAMS

Seeing meteors pepper the sky from the direction of Lyra is a regular April event. Unfortunately, moonlight significantly hinders observations of this year's Lyrid meteor shower. The Lyrids peak near midnight EDT the night of April 21/22, when a waning gibbous Moon stands in Libra. To get a decent view, watch before dawn April 22 from a spot where trees or buildings block the Moon.

A better opportunity to see meteors arises in April's final days. Although the Eta Aquarid shower doesn't peak until May's first week, its annual run begins late this month. The meteors come from debris left behind by Comet 1P/Halley during its passages through the inner solar system.

The International Meteor Organization reports an apparent 12-year activity cycle for the Eta Aquarids. This could boost rates from 2008 to 2010. So, despite the radiant's low altitude from the Northern Hemisphere, watch for the Eta Aquarids' typically long streaks.

X MARKS THE SPOT

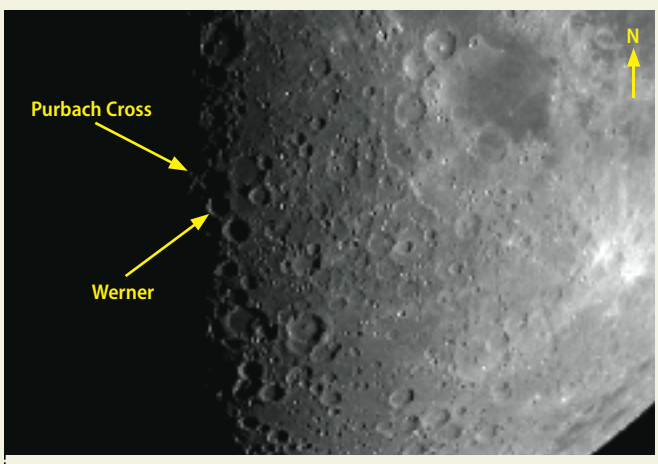
It's a startling sight: Smack in the middle of the Moon — on the dark side of the terminator south of the equator — lies a brightly illuminated "X." Mark your calendar for April 12 at 8 P.M. EDT. Then watch as a few pinpoints grow into the well-defined letter. Within another 2 hours, it dissolves into the advancing moonscape.

Sometimes called the Purbach Cross or the Werner X (after nearby named craters), the feature develops when sunlight first illuminates the higher terrain of four craters in edge-to-edge contact. You might expect the X to have rounded arms, but the play of light along the craters' irregular walls produces this chance arrangement.

If you use a lunar atlas to navigate this area at a different time, the X lies one-crater-width northwest of Werner.

With this month's perfect timing, you can create a time-lapse movie of the X emerging, peaking, and disappearing. Simply take webcam clips every 5 to 10 minutes and combine them in a program like *Photoshop*. Oddly, despite its prominence every couple of months, the X has appeared in lunar observations only in the past decade or so. Perhaps because it's just a coincidental alignment and has no physical importance, earlier Moon watchers simply didn't bother reporting it.

You can't see this quaint feature of shadow and light every month from a single location because the Moon's phase repeats approximately every 29.53 days. If you observe the Moon 29 days after the X appears, sunrise over the feature will be about 12 hours away. And by the next night, the X has been washed out for 12 hours.



THE PURBACH CROSS (sometimes called the Werner X) stands out on the dark side of the Moon as a distinctive "X" right around first quarter phase. ALISTER LING

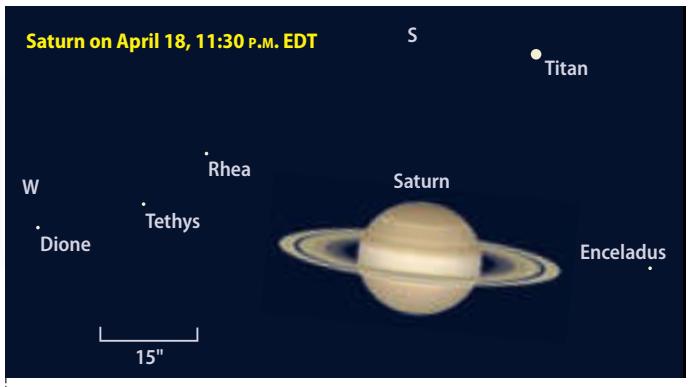
/// WHEN TO VIEW THE PLANETS

EVENING SKY	MIDNIGHT	MORNING SKY
Mercury (west)	Mars (west)	Jupiter (southeast)
Mars (southwest)	Saturn (southwest)	Uranus (east)
Saturn (southeast)		

brightest point of light in the sky then. Watch the waning gibbous Moon pass 3° below Jupiter the morning of April 27.

Jupiter's disk grows from 37" to 41" during April as the gap between it and Earth narrows by 43 million miles. Although opposition and best visibility remain 3 months away, the solar system's largest planet appears big enough for small telescopes to show lots of detail. Jupiter's dynamic atmosphere features an alternating series of bright zones and dark belts parallel to the planet's equator. Much of the planet's activity plays out near the boundaries between these bands.

Jupiter stays among the background stars of eastern Sagittarius all year. This southern constellation never climbs high in the sky for northern observers, so Jupiter's light has to pass through more of Earth's atmosphere on its way to our telescopes. The poor seeing that results will hinder observations, although curious observers will be eager to see what effects remain from last year's jovian upheaval. In 2007, huge disturbances wracked the planet's southern hemisphere.



SATURN'S MOONS present a constantly changing canvas. Any telescope will show you 8th-magnitude Titan, while a 6-inch scope brings several more into view. *ASTRONOMY:* JAY SMITH

Any telescope will show the four bright Galilean moons: Io, Europa, Ganymede, and Callisto. Io circles Jupiter in less than 2 days, and, once each orbit, its dark shadow transits the planet's disk. The other three moons' shadows do the same thing, only less frequently.

Jupiter also occults each moon as it passes behind the planet. Jupiter's shadow now extends west of the planet's disk, so each moon passes into the shadow before an occultation occurs. These jovian lunar eclipses are easy to observe. At the end of an occultation, each moon reappears from behind Jupiter's eastern limb.

One constellation east of Sagittarius is the home of the

A COMET AND A FERRET

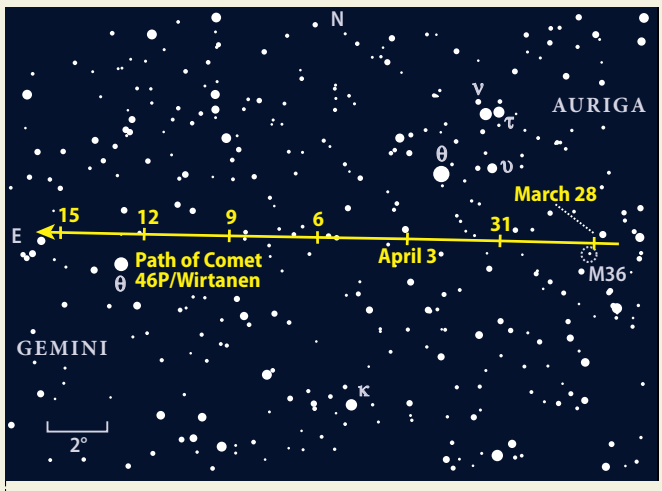
The prolific 18th-century French comet hunter Charles Messier — nicknamed the "ferret" for his ability to root out comets from the sky — remains best known for his catalog of star clusters and nebulae. In early April, the short-period comet 46P/Wirtanen lies near Messier's 36th catalog entry: the splashy star cluster M36. (The comet passed a mere 10' north of the cluster March 28/29.)

Glowing with the combined light of an 11th-magnitude star, the comet will appear considerably fainter than the cluster, and likely won't be visible from suburban backyards. The comet's light spreads out, which makes it a "faint fuzzy" and requires a trip to a dark-sky site for a good view. The interplanetary missile lies high in the evening sky, among the background stars of Auriga.

Although Messier began his catalog to mark comet look-alikes, he expanded it to include star clusters that might appear fuzzy in smaller, low-quality telescopes.

By the time Comet Wirtanen reaches 4th-magnitude Theta (θ) Geminorum in mid-April, it has faded to 12th magnitude. That takes it out of the range of most 6-inch scopes and presents a considerable challenge for an 8-inch.

American astronomer Carl Wirtanen (1910–1990) discovered this comet January 17, 1948, from California's Lick Observatory. It was recorded on photographic plates taken 2 nights earlier for a survey determining the proper motions of stars. This Jupiter-family comet takes 5.4 years to orbit the Sun.



COMET 46P/WIRTANEN glows at 11th magnitude early this month. A highlight comes in late March and early April, when the comet lies near the bright star cluster M36. *ASTRONOMY:* JAY SMITH

Wirtanen originally was the primary target for the European Space Agency's robotic orbiter and lander mission called Rosetta. Wirtanen slipped out of reach as Rosetta's launch was delayed. The spacecraft now is heading toward a rendezvous with Comet 67P/Churyumov-Gerasimenko in 2014.

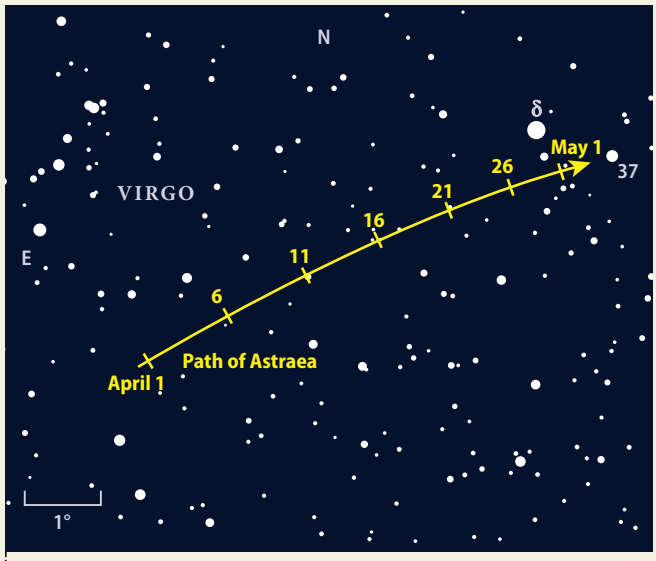
ASTRAEA STANDS OUT

In astronomy, brighter isn't always better. Asteroid 5 Astraea now has nowhere to hide among the smattering of faint background stars in Virgo. Peaking at magnitude 9.4, this main-belt asteroid glows brighter than any other object in the field for much of its journey. From the suburbs, a 4-inch scope will gather enough light for you to track down this space rock.

In contrast, asteroid 1 Ceres appears half a magnitude brighter, but it travels in front of a rich Milky Way star field in Taurus. The profusion of background stars brighter than Ceres effectively camouflages the solar system's largest asteroid.

On the evening of April 21, Astraea slides a bare 2' south of a 9th-magnitude star. This gives you an opportunity to watch a solar system object move in the course of an evening. If you sketch the changing scene, an 11th-magnitude field star just to the west will help you orient the sketch.

Astraea rocked the solar system when amateur astronomer Karl Hencke discovered it in 1845. Astronomers had conveniently (but wrongly) interpreted the "Big Four" asteroids — Ceres, Pallas, Juno, and Vesta — as chunks of a "missing" planet between Mars and Jupiter. Astraea forced scientists to rethink the solar system and move toward the concept of an asteroid belt.



ASTEROID ASTRAEA peaks at magnitude 9.4 this month but stands out nonetheless against the rather barren star field of the constellation Virgo. *ASTRONOMY:* JAY SMITH

solar system's outermost planet. **Neptune** lies in northeastern Capricornus, a region that stands 15° high in the southeast when morning twilight begins in late April. Neptune glows at magnitude 7.9, so you'll need binoculars to spot it.

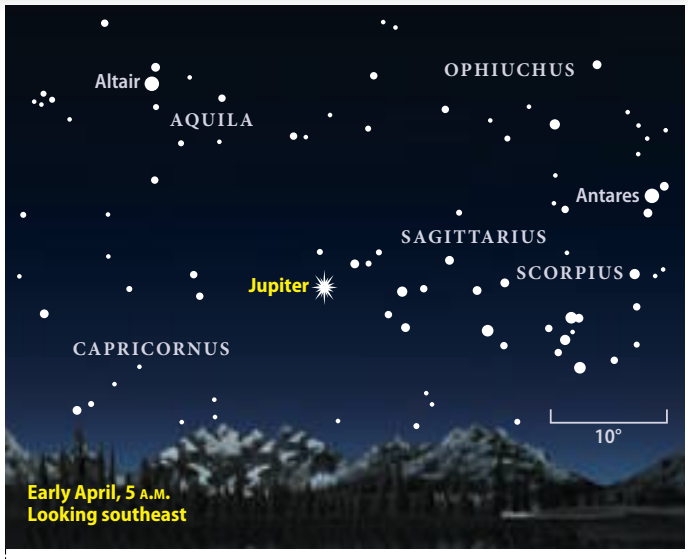
At least it's easy to find the correct field: Neptune lies 2.4° due north of 3rd-magnitude Delta (δ) Capricorni, the brightest star at the Sea Goat's eastern end. A line of three 5th- and 6th-magnitude stars lies just 1° southwest of Neptune.

Uranus lies in the next constellation east, Aquarius. The 6th-magnitude planet barely clears the horizon by the time twilight begins in late April, however, so it's probably best to wait until May before tracking it down.

For observers at mid-northern latitudes, **Venus** lies too deep in the solar glare to see reliably. You might catch a brief glimpse April 1, when the brilliant planet rises barely 30 minutes before the Sun. (From the Southern Hemisphere, Venus comes up nearly 90 minutes before sunrise and appears conspicuous.)

Mercury suffers the same fate as April begins: It's visible from the south but not the north. The inner planet zips around the Sun, however, and reappears on evenings in late April. On the 30th, Mercury shines brightly at magnitude –1.0 and lies nearly 10° high in the west-northwest half an hour after sunset. The planet appears 4° below the Pleiades star cluster (M45) as the sky starts to darken. This apparition peaks in May, when Mercury puts on its best evening show of the year.

The Pleiades also plays a role in one of April's finest events. On the 8th, the waxing crescent Moon grazes the cluster's northern edge. The slender 3-day-old Moon blocks, or occults, several of the fainter Pleiads from view. For example, the Moon's dark limb occults 4th-magnitude Taygeta (19 Tauri) around 9 P.M. CDT for observers in the central Midwest. Times will vary significantly at other geographic locations.



BRILLIANT JUPITER dominates April mornings. It climbs higher as the weeks pass and outshines every other point of light in the predawn sky. *ASTRONOMY:* JAY SMITH

Binoculars will offer a spectacular view of the whole event, while telescopes will allow you to time each disappearance accurately. The Moon lies fairly low in the west for East Coast observers, and progressively higher the farther west you go. To find accurate times for your observing location, visit the International Occultation Timing Association's web site at www.lunar-occultations.com.

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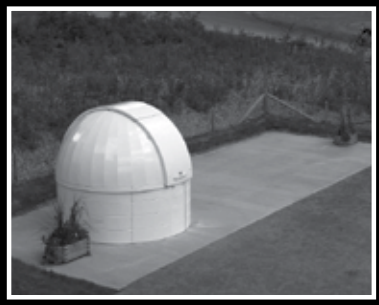

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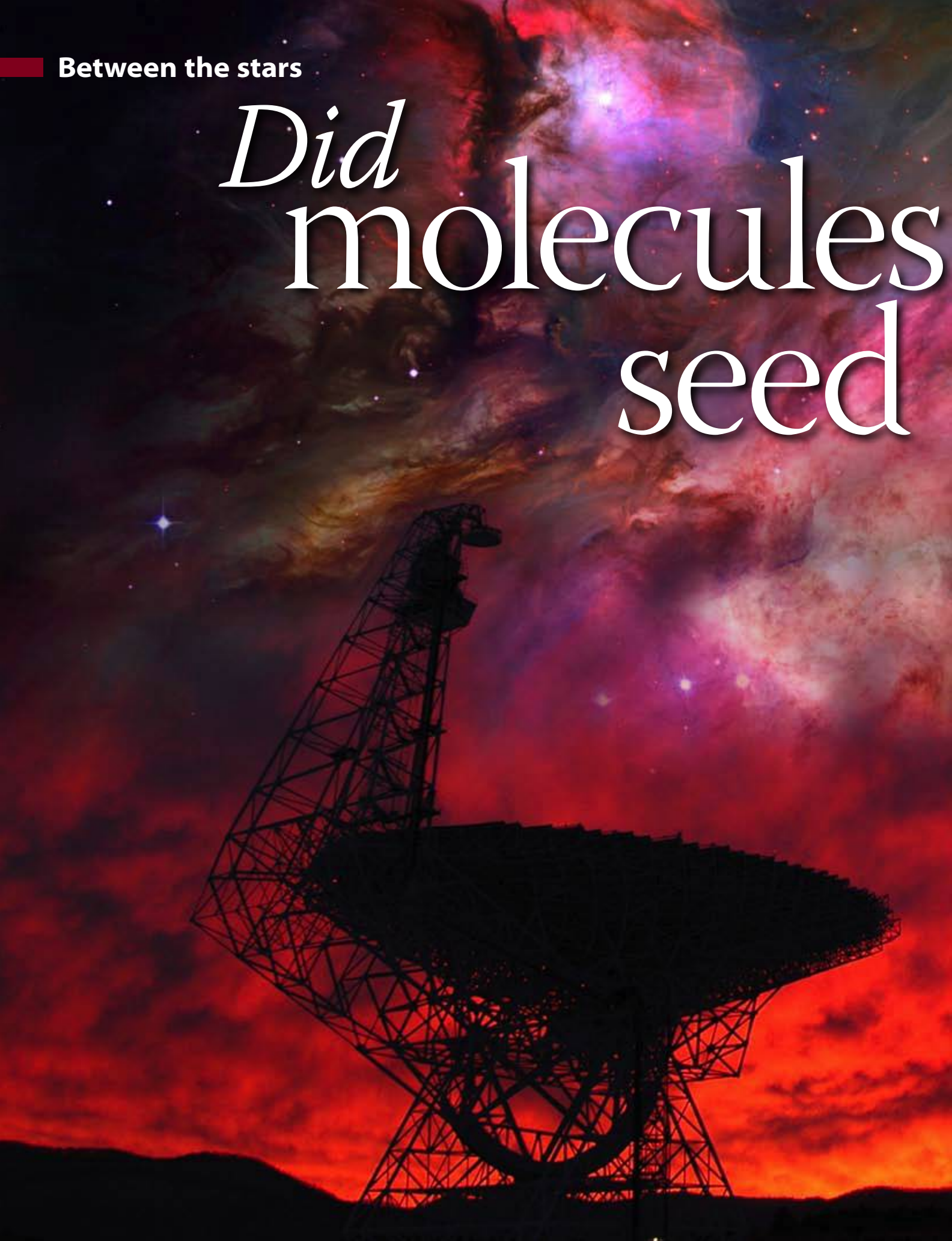
Did molecules seed



from space life *in the cosmos?*

Astronomers have detected more than 150 different molecules in interstellar space. Now, scientists want to learn how these molecules might have jump-started life. /// **BY BRUCE DORMINEY**

Sitting on Earth amid a sea of complex molecules, we can easily forget these building blocks of the physical world are much harder to come by outside our solar system. Large distances, low densities, and faint signals conspire to make molecule-hunting a difficult task. Still, dense molecular clouds like the one in which the solar system formed some 4.6 billion years ago show up throughout the galaxy.

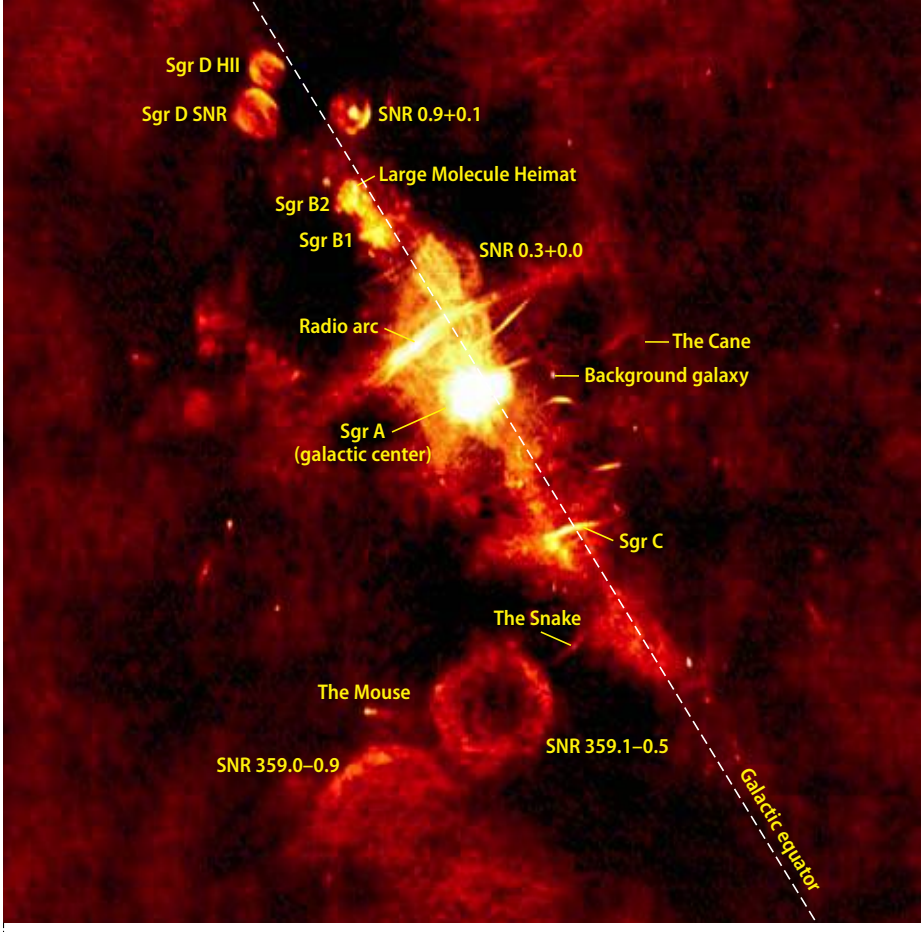
Astronomers discovered the first interstellar molecules in the 1930s. Optical and ultraviolet observations turned up simple diatomic molecules — those consisting of two atoms bound together. Now, sensitive instruments detect common species like molecular hydrogen and carbon monoxide in the distant cosmos.

But the hunt for complex molecules, with complex usually defined as more than 8 atoms, didn't take off until the advent of high-resolution radio spectra of nearby interstellar clouds. Carbon-based (or organic) molecules — the building blocks for all life as we know it — make up the most complex molecules known. These pique the interest of astrobiologists, who wonder whether organic molecules could lead to life elsewhere.

As of early 2008, astronomers have detected more than 150 molecules in the interstellar medium (ISM). The largest is the 13-atom-long, carbon-chain molecule cyanodecapentayne ($HC_{11}N$). It doesn't occur naturally on Earth.

Detecting such complex molecules requires observational perseverance and dogged detective work. Scientists first must

THIS COMPOSITE photo shows the Green Bank Telescope at sunset beneath the Orion Nebula (M42). The 485-foot-tall (148m) radio scope has detected many molecules in M42 and elsewhere. TELESCOPE: NRAO/AUI/HARRY MORTON (NRAO); M42 (TOP): NASA/ESA/M. ROBBERTO (STScI/ESA)



THE MILKY WAY'S CENTER, which lies hidden behind dust and gas at visible wavelengths, glows brightly at a radio wavelength of about 40 inches (1m). Molecules abound in the Large Molecule Heimat, a hot core located inside Sagittarius B2 (Sgr B2). NRAO/AUI/N. KASSIM (NRL)

measure molecular spectra in the laboratory. Then, astronomers compare this spectral data with what their radio telescopes see. Out of billions of possible molecules lurking in molecular clouds, astrochemists detect only a handful each year.

From clouds to stars

The largest and densest of these interstellar clouds, which can span a few hundred light-years, apparently owe their existence to spiral density waves. These waves radiate from the galaxy's center into the disk. Analogous to sound waves, density waves create supersonic shocks as they roll through low-density gas clouds. The shock waves compress existing molecules spewed from previous generations of stars, creating dense clouds which, in turn, spawn molecules of increasing complexity.

"Grand design spiral galaxies, such as M51 [the Whirlpool Galaxy] and our Milky Way Galaxy, have strong spiral density waves with molecular clouds strongly concentrated in the spiral arms," says Leo Blitz, a radio astronomer at the University of California, Berkeley. "That means the clouds must have formed there."

Once these giant molecular clouds reach masses a million times the Sun's, regions within them become unstable. They start collapsing into hundreds of thousands of protostellar nebulae that eventually will form both high- and low-mass stars.

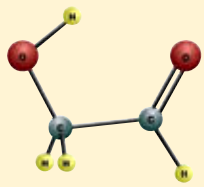
"High-mass star formation can then trigger supernova-induced star formation," says Debra Elmegreen, an observational astronomer at Vassar College. "About 10 percent of a molecular cloud's mass will turn into stars, but in the process of star formation, the cloud itself gets destroyed. Dense molecular clouds tend to last only hundreds of millions of years."

Our Sun appears to have been triggered by such a follow-on supernova. But the molecular cloud that spawned the Sun dissipated long ago.

Since beginning his work more than 3 decades ago, astrophysicist Jan M. Hollis at NASA's Goddard Space Flight Center has discovered more than a dozen molecules in the ISM. In 2000, his team detected glycolaldehyde, a simpler cousin of table sugar. Four years later, he confirmed its presence in a frigid region surrounding the Large Molecule Heimat — a hot molecular core that eventually will form a massive star — in the Sagittarius B2 complex. This complex, the best source of interstellar molecules known, lies near the Milky Way's center.

"When the National Radio Astronomy Observatory's Green Bank Telescope in West Virginia came on-line in 2004," says Hollis, "I saw glycolaldehyde both in emission and absorption, and figured out the temperatures were on the order of a very cold 8 Kelvin" — just 8° Celsius (14° Fahrenheit) above absolute zero.

Molecules in the gas phase rotate freely. Each time a molecule rotates, it either emits or absorbs photons at specific radio frequencies. Knowing these frequencies from laboratory measurements, radio astronomers can identify specific molecular species via a single to a few dozen spectral lines.



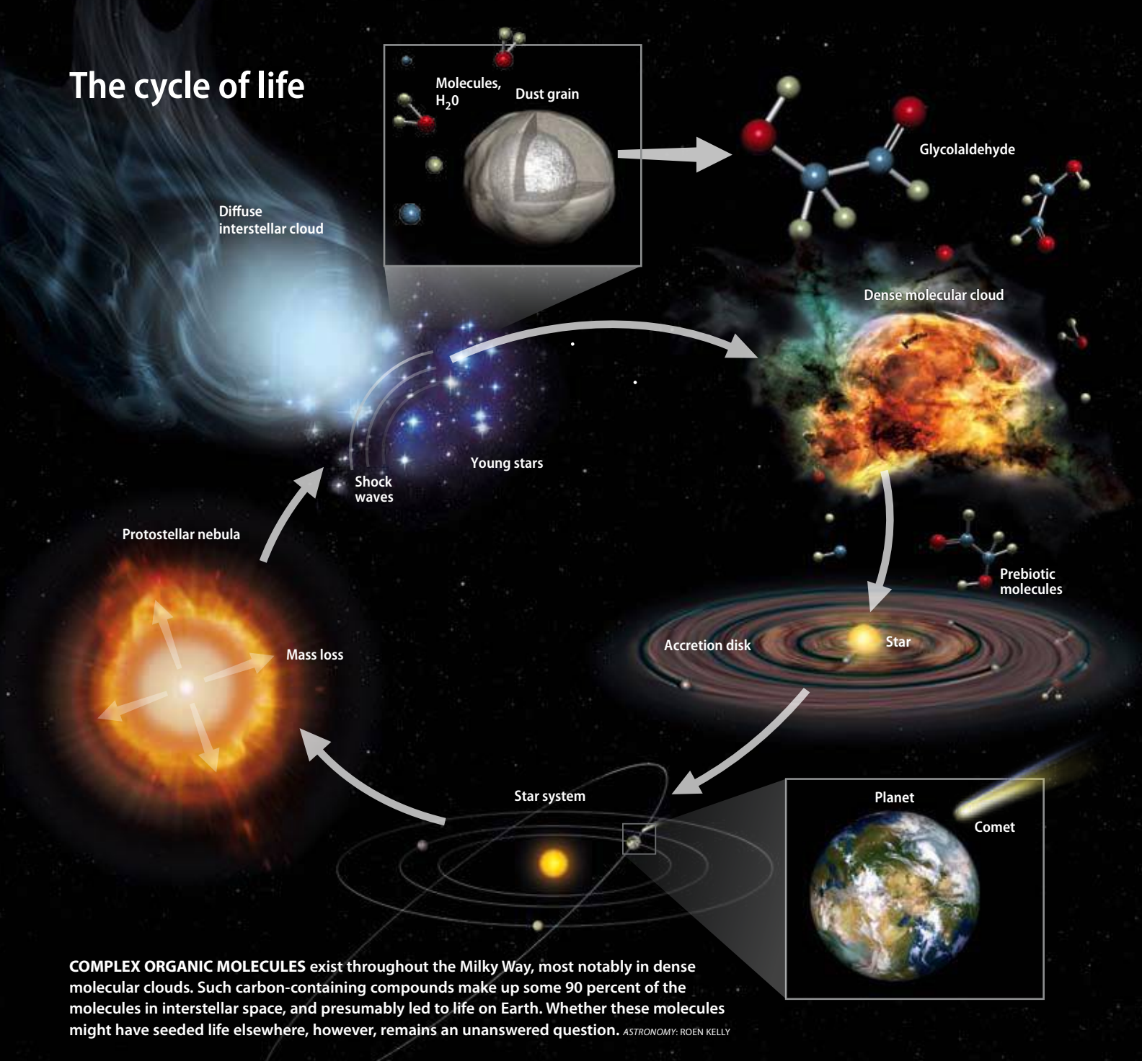
THE MOLECULE glycolaldehyde (CH_2OHCHO), a simple sugar, is abundant in the Large Molecule Heimat. This molecule's discovery fueled scientists' speculation that the building blocks of life are common in our galaxy. *ASTRONOMY:* ROEN KELLY

An acidic search

The more rigid a molecule, the easier it is to verify. But amino acids flop around a lot and are more difficult to pin down

THE MURCHISON METEORITE contains particles (seen in the test tube) that condensed from material ejected by stars that predate the Sun. ARGONNE NATIONAL LABORATORY

Bruce Dorminey *is the author of* Distant Wanderers: The Search for Planets Beyond the Solar System *(Copernicus Books, 2001). His most recent* Astronomy *article was "On the trail of hydrogen's heavy sibling" in February 2008.*



COMPLEX ORGANIC MOLECULES exist throughout the Milky Way, most notably in dense molecular clouds. Such carbon-containing compounds make up some 90 percent of the molecules in interstellar space, and presumably led to life on Earth. Whether these molecules might have seeded life elsewhere, however, remains an unanswered question. *ASTRONOMY*: ROEN KELLY

spectroscopically. When such molecules are excited enough to emit photons at radio frequencies, the emission gets spread out and is weaker.

"The bigger the molecule, the more spectral lines there will be," says William Klemperer, a spectroscopist and physical chemist at Harvard University. "You really have to know the line perfectly to identify it, especially if it's a weak line."

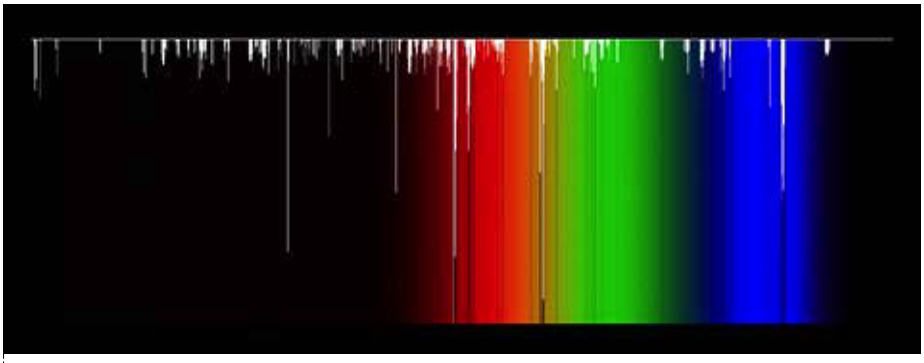
Since the late 1970s, astronomers have sought interstellar glycine, the simplest amino acid, almost to the point of obsession. "I've convinced myself that if it's there, it's below the detectability limit of any telescope I've ever used," says Hollis. "No one has shown convincing evidence it's there."

Yi-Jehng Kuan, an astrophysicist at the National Taiwan Normal University in Taipei, would beg to differ. In 2003, Kuan and his colleagues reported interstellar glycine in nearly twenty different spectral bands in several sources. Most astrochemists applaud Kuan for a valiant effort, but don't think his team has found this elusive molecule. Yet Kuan stands by his detection.

"Once you integrate down to a certain point," says University of Michigan astrochemist Ted Bergin, "you hit the line confusion limit, where you basically get a blend of lines from who-the-heck-knows-what. And amongst that line forest you could pick out any species in the world and say that you've detected it. It's absolutely certain that some of the lines Kuan detected are incorrectly identified."

On the road to life

Amino acids may form easily in the ISM, in protostellar nebulae, and on young, earthlike planets. But the hope is that the next generation of astrochemists and



DIFFUSE INTERSTELLAR BANDS (DIBs) are absorption features in spectra of stars in the Milky Way and nearby galaxies. Astronomers have discovered hundreds of DIBs, which appear as the white dips in this composite spectrum ranging from the infrared (at left) through visible to the ultraviolet. P. JENNISKENS/SETI INSTITUTE

astrobiologists will finally nail down the specific interstellar chemistry that was essential to life's evolution on Earth.

That's a tall order, because the interstellar molecules astrochemists hope to detect are, for the most part, also found on our planet. One of many conundrums is how to determine which organic molecules survived the journey from the ISM into our nascent planetary system.

"The more we probe, the more complex the organic chemistry gets," says Lucy Ziurys, an astrochemist at the University of Arizona. "If ISM chemistry supplied certain materials in preference to other materials, that would explain why biochemistry went the way it did. Our biochemistry could have gone in 20 different directions. So, the origin of life may have a really direct interstellar connection. We're trying to put together a picture and we only have 10 percent of the data."

Over the past decade or so, conventional wisdom held that all the interesting chemistry really occurs in hot cores, like the Large Molecule Heimat. But, as Hollis attests, most complicated interstellar molecules appear to form in the colder regions of those clouds. This suggests prebiotic molecules are even more widespread than previously believed.

If so, would they have survived the collapse of our protosolar nebula? Or, to look at it another way, could life have started without being seeded by molecules created in the dense molecular cloud from which the solar nebula collapsed?

Max Bernstein, an astrochemist at NASA's Ames Research Center, notes glycine should be present in all large, dense molecular clouds. He says the amino acids detected in the Murchison meteorite, which landed in Australia in September 1969, and others may have been nitriles (ironically, a form of cyanide) at the time the solar system formed. These nitriles then may have reacted with water to form amino acids. They retained their heavy hydrogen isotope deuterium because the carbon-carbon and carbon-hydrogen bonds all survived.

"To go from a nitrile to an acid," says Bernstein, "all you have to do is put it in water and wait. When you see very high deuterium enrichment in amino acids in the Murchison meteorite, it's definitely an indication of a low-temperature synthesis. And dense molecular clouds are the places where you get the largest deuterium enrichments."

Early planetary processes also can transform organic molecules into biologically interesting materials, says research chemist Steven Benner of the Foundation for Applied Molecular Evolution in Gainesville, Florida. The sugar alcohol glycerol, which is abundant in meteorites, can be transformed into a form of the simple carbohydrate dihydroxyacetone. And, in the presence of borate minerals, this molecule can produce ribose, a precursor of RNA.

THE ATACAMA Large Millimeter Array, being built in northern Chile, will hunt down interstellar molecules that have eluded detection so far. ESO

"Some astronomers seem to think that the detection of an amino acid out there somewhere means life," says Pascale Ehrenfreund, an astrochemist and astrobiologist at the University of Leiden in the Netherlands. "But there is an incredible gap between carbon compounds and the complexity of a cell."

DIBs on life

Regardless of how it happened, we are living proof that life formed around at least one star. But what does astrochemistry tell us about the abundance of life elsewhere? A partial answer may have its roots in spectroscopic observations done some 85 years ago at California's Lick Observatory.

Since the 1920s, astronomers have puzzled over the presence of what they now call Diffuse Interstellar Bands (DIBs). To date, researchers have found more than 500 DIBs in optical and ultraviolet spectra of stars throughout the Milky Way and a handful of nearby galaxies.

The leading candidate for DIBs "carriers" are polycyclic aromatic hydrocarbons (PAHs). These molecules account for 20

GLOWING GAS in this infrared image of Barnard 30, a star-forming region in Orion, traces the presence of polycyclic aromatic hydrocarbons (PAHs). Many researchers think PAHs or other large carbon molecules create Diffuse Interstellar Bands. NASA/JPL-CALTECH/D. BARRADO Y NAVASCUÉS (LAEFF-INTA)

percent of all cosmic carbon. On Earth, PAHs exist in everything from naphthalene, the active agent in mothballs, to the carcinogenic byproducts of petroleum refineries, soot, road tar, forest fires, and charbroiled meats.

The view that DIBs could be related to some sort of PAH or other large, carbon-chain molecule, such as fullerenes, has been around since the 1950s. But the idea is not without its critics.

Klemperer is unsure because DIBs lack a spectral smoking gun. He thinks the putative link between PAHs and DIBs is tenuous at best, and attributes such theories to wishful astrobiology.

How much life is out there?

Half of the carbon delivered to Earth comes as some sort of hydrocarbon. Astrobiology proponents find PAHs attractive because the molecules are robust enough to absorb ultraviolet radiation without breaking up. Nature then can use them directly in key proto-cellular processes.

The trouble is, the ubiquity of PAHs has a direct correlation with the age of the universe. They tend to fall off at early cosmic times. We know carbon formation peaked around 7 billion years ago, when the universe was half its current age. However, best estimates put the creation of prebiotic molecules 3 to 4 billion years earlier.

So, how did we get from there to here? As Benner points out, human chromosome 22 has roughly 100 million nucleic acids in its sequence, encompassing about a billion atoms total. "It takes some doing to keep that molecule together," he says. "If you heat it or shake it, it will fall apart."

Such biologically complex molecules aren't floating around anywhere in the diffuse interstellar medium. Yet here on Earth, they're everywhere. And that's the rub: How can scientists bridge the gap between interstellar astrochemistry and Earth-based biology?

Filling in the gaps so we can make sweeping generalizations about the likelihood of life in the universe will require an interdisciplinary effort, one that effectively unites paleobiologists, astrobiologists, and astrochemists.

And that still may not be enough. Answering age-old questions about the serendipitous sequence of events that led to the creation of a habitable, bio-rich solar system like ours, much less figuring out which interstellar molecules were crucial for the development of life on Earth, simply may not be possible. The hardest lesson for astrobiologists may be that there is no molecular Rosetta Stone, no guarantee astrochemistry will always vector into life.

"We know that the early solar system received a delivery of interstellar protosolar molecules," says Bernstein. "But the formation of life in our solar system was an historical event. So, ultimately, how are we ever going to know that these interstellar molecules weren't necessary?" A

WEB EXTRA To learn more about the Atacama Large Millimeter Array, visit www.Astronomy.com/toc.

Stardust's NExT mission targets Comet Tempel 1

STARDUST MISSION

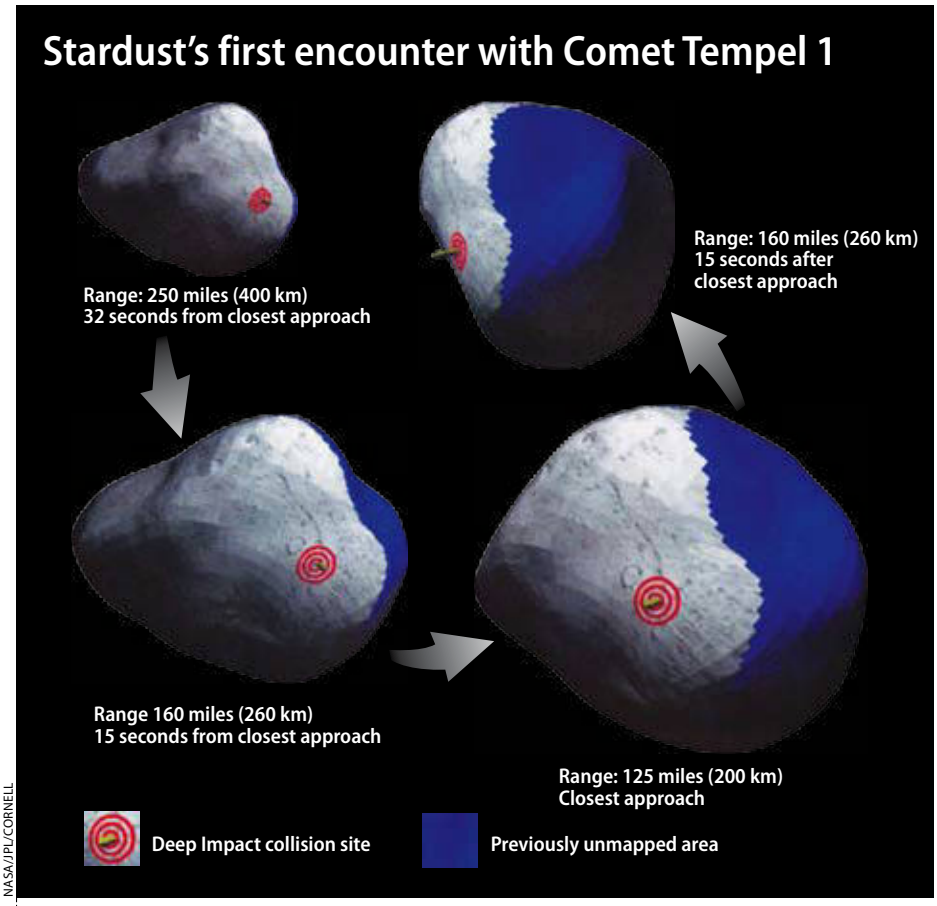
Q: What is the Stardust spacecraft's mission now that it has returned comet samples to Earth? — **GRACE PHILLIPS,** WEST BEND, OREGON

A: After delivering its comet-dust cargo to Earth January 15, 2006, the Stardust spacecraft orbited Earth then "hibernated" for 6 months. **On August 13, 2007, Stardust was reactivated and began its next mission: the New Exploration of Tempel 1 (NExT).**

Stardust will visit Comet 9P/Tempel 1, the same comet the Deep Impact mission pummeled July 4, 2005.

NExT is scheduled to fly past Tempel 1 February 14, 2011. It will extend the mapping of Tempel 1 begun by Deep Impact.

Stardust's new mission will let scientists look at the changes in Comet Tempel 1's nucleus since Deep Impact's flyby. This will mark the first time a comet has ever been revisited. — **SCOTT SANDFORD,** STARDUST CO-INVESTIGATOR, NASA-AMES RESEARCH CENTER


Stardust's first encounter with Comet Tempel 1
Range: 250 miles (400 km)
32 seconds from closest approach
Range: 160 miles (260 km)
15 seconds after
closest approach
Range 160 miles (260 km)
15 seconds from closest approach
Range: 125 miles (200 km)
Closest approach
Deep Impact collision site
Previously unmapped area

NASA/JPL/CORNELL

STARDUST NExT WILL VISIT COMET 9P/TEMPEL 1 in February 2011. The spacecraft will pass within 125 miles (200 km) to examine the crater made when the Deep Impact spacecraft impacted the comet's nucleus. It will also map the icy body in greater detail.

CHOOSING EQUIPMENT

Q: Should I purchase a 1¼" or 2" star diagonal for my new telescope? — **HOWARD FOLEY,** SPRINGFIELD, ILLINOIS

A: Your choice of diagonal depends on your photographic equipment. **If you have a CCD camera, get the larger diagonal. But, if you'll shoot with a large-megapixel digital SLR, a 1¼" diagonal will work.**

Two-inch eyepieces have a larger field of view, but you have to weigh the cost. Your best bet might be to try several different eyepieces (owned by others) at star parties or astronomy club events once you've purchased your scope. — **MICHAEL E. BAKICH,** SENIOR EDITOR

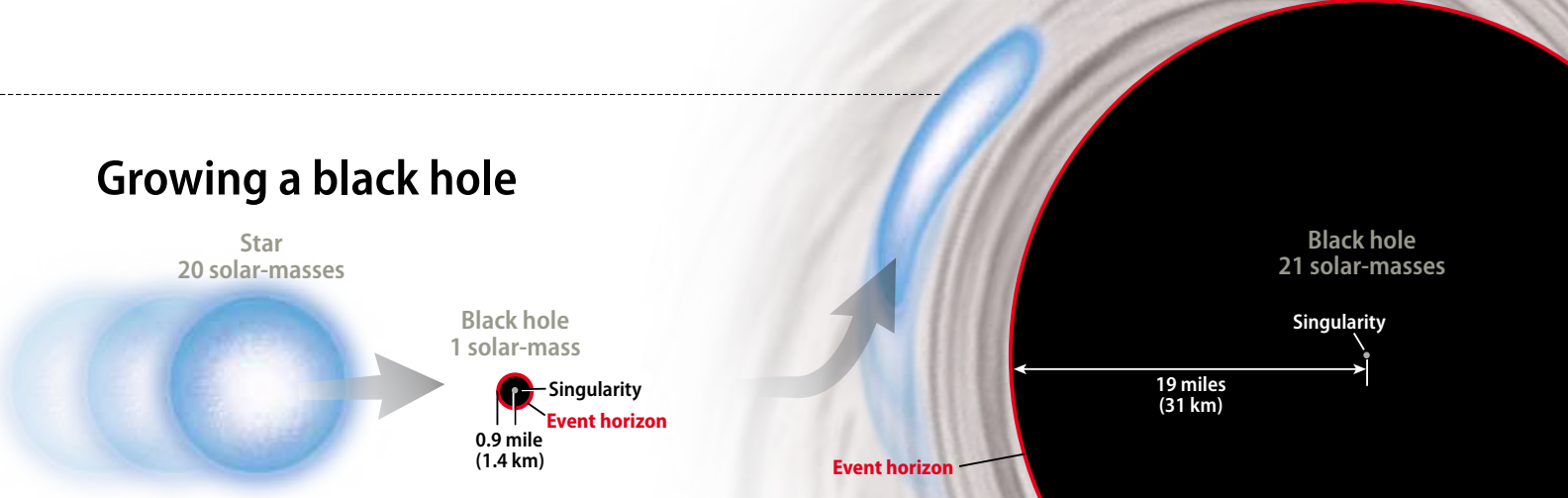
PAN-WHAT?

Q: What is the theory of panspermia? — **FATIMA FIZBIT,** NORTH LAS VEGAS, NEVADA

A: The panspermia hypothesis suggests life began on Earth when the "seeds" of life, already present in the universe, arrived here from space. How did these seeds, or microbes, get here? Proposed transport methods include meteorites, comets, and spacecraft.

Greek philosopher Anaxagoras wrote about the idea in the 5th century B.C. Since then, other scientists, including British astronomer Sir Frederick Hoyle (1915–2001), believed panspermia not only explained how life originated here, but also proposed the process continues to bring

Growing a black hole



A BLACK HOLE'S event horizon grows as the black hole consumes mass. The more mass it consumes, the farther away the boundary will appear from our perspective. *ASTRONOMY:* ROEN KELLY

microbes or other life-forms to Earth.
— **LAURA LAYTON,** ASSOCIATE EDITOR

BLACK-HOLE GROWTH

Q: If time stops at a singularity, how can massive black holes grow? — **JIM GAMPETRO,** BUFFALO, WYOMING

A: Matter falling onto a black hole's event horizon appears to slow down and "freeze" to an observer outside the event horizon. If you dropped a coin at an event horizon, you would have to wait until the end of time to see it pass beyond the horizon.

For example, the event horizon of a small, one-solar-mass black hole has a radius of about 0.9 mile (1.4 km). If we dump 20 solar-masses of new material on the small black hole, we'll never see the new mass get any closer.

However, as the new mass approaches about 19 miles (31 km) from the event horizon, something happens. **A new event horizon emerges, larger than the original one, and to an outside observer, the black hole appears to "grow."** Things are very strange near a black hole. — **SIMON DEDEO,** KAVLI INSTITUTE FOR COSMOLOGICAL PHYSICS, UNIVERSITY OF CHICAGO

WOBBLY MOON

Q: Does the Moon wobble? — **PATRICIA WILLIS,** COLUMBUS, OHIO

A: Yes. The direction of the Moon's axis of rotation moves with respect to its north-south axis and with respect to the stars.

If you were on the Moon tracing out the direction of the axis of rotation on the surface near its north pole, you would see an elliptical path of about 0.8 by 1.3 miles (1.3 by 2.1 kilometers) plus much smaller variations. Each cycle of the large elliptical motion takes 6 years.

Other motions also describe the Moon's three-dimensional orientation. The Moon rotates once every 27.3 days on average, but this rotation rate is not quite uniform. The lunar equator tilts 1.54° to the ecliptic plane and precesses with an 18.6-year period. But again, there are small additional variations in the lunar equator's orientation. Collectively, these small, non-uniform parts of the rotation and equator orientation are called physical librations.

Because the Moon is not perfectly spherical, Earth's gravitational pull on the Moon's lumpy figure twists it. These pulls cause the physical libration variations.
— **JAMES WILLIAMS,** STARDUST SCIENCE TEAM, NASA'S JET PROPULSION LABORATORY, CALIFORNIA INSTITUTE OF TECHNOLOGY, PASADENA

IN THE KNOW

CCD
A silicon chip used to detect light; charge-coupled devices are more efficient at collecting light than conventional film.

STAR DIAGONAL
A telescope accessory that allows you to mount an eyepiece at a 90° angle to the back of a telescope's optical tube.

EVENT HORIZON
The boundary of a black hole beyond which, once crossed, light and matter cannot escape.

PRECESSION
The change in direction of a rotating body's axis.

LIBRATIONS
Variations in the orientation of the Moon's surface relative to an earthly observer caused by the Moon's changing orbital speed, the changing tilt of its axis, and the observer's changing perspective.

COMING NEXT MONTH ...
Where's the best place to view the northern lights? Post your comments about this question online at www.astronomy.com/forums.

Send your questions via e-mail to: askastro@astronomy.com; or write to: Ask Astro, P. O. Box 1612, Waukesha, WI 53187. Be sure to tell us your full name and where you live. Unfortunately, we cannot answer all questions submitted.

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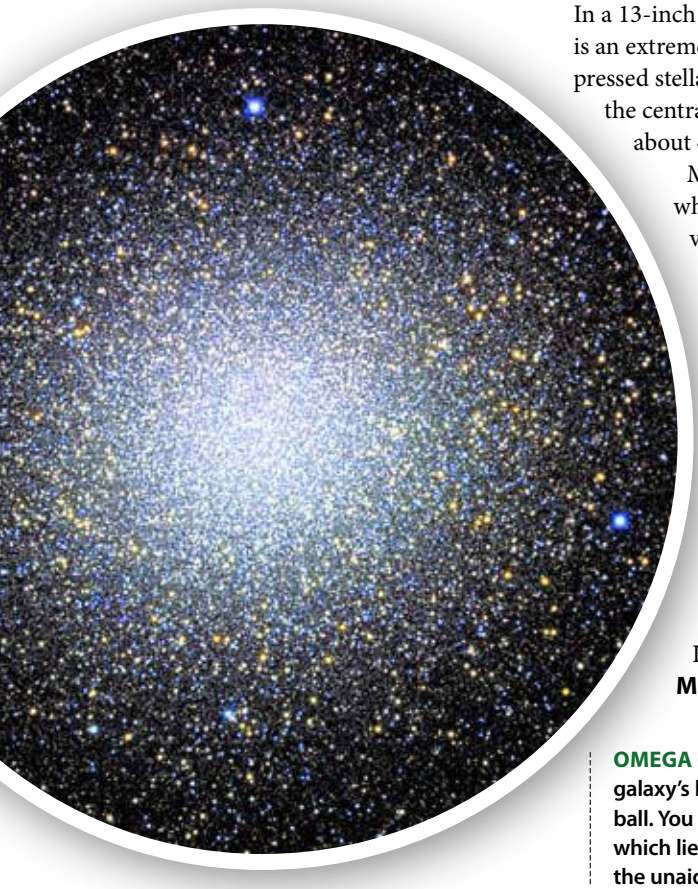
Spot spring's 11 be

From Omega Centauri to M5, spring's globulars offer diverse targets for all observers.

/// BY STEVE COE



OMEGA CENTAURI (NGC 5139) is our galaxy's largest and most massive star ball. You can see this globular cluster, which lies 15,000 light-years away, with the unaided eye. DANIEL VERSCHATSE

Globular star clusters, those ancient relics of our galaxy's formative years, are some of the most visually appealing deep-sky objects. Although they congregate in the summer constellations near the Milky Way's center — Scorpius, Sagittarius, and Ophiuchus — you can target globular clusters in any season. Here we'll take a look at spring's globular gems.

Start with the king

Omega Centauri (NGC 5139), the king of the globular clusters, is easily visible with the naked eye from even moderately dark skies. Located in the far southern sky, the object just skims the horizon for many northern observers. Even so, it's impressive. In a 13-inch Newtonian at 100x, the cluster is an extremely bright, rich, and compressed stellar swarm that extends 45' from the central core. I'm able to resolve about 400 stars.

My best view came in 1986, when I traveled to Australia to view Halley's Comet. When I used a friend's 12-inch f/6, Omega Centauri filled the field of view in all directions at 140x magnification. With this magnificent globular 80° above the horizon, many starry chains meandered outward from the cluster's blazing core.

Berenices' jeweled hair

English astronomer William Herschel (1738–1822) called **M53** (NGC 5024) in Coma Ber-

ASTRONOMER William Herschel called M53 one of the most beautiful sights in the heavens. Compare direct views with what you see using averted vision. AL KELLY

enices "one of the most beautiful sights I remember to have seen in the heavens." The cluster is so bright I can see it in my 13-inch scope's 11x80 finder as a silvery glow.

In the scope itself, at 165x, M53 appears bright, large, and compressed with an extra-bright center. I can resolve about 50 stars in the outer sections, and, at 220x, 10 stars in the cluster's core.

Views using direct and averted vision — a technique of looking indirectly at the cluster to enhance your view — are remarkably different. Averted vision almost doubles the size of this globular. This technique exposes more of the cluster's faint glow to ultrasensitive light-sensing cells that lie outside the normal center of vision.

Nearby **NGC 5053** stands in stark contrast to M53. The cluster looks large and faint, with an irregular, round shape. Even in an 11-inch Schmidt-Cassegrain (SCT) at 125x, the center of NGC 5053 doesn't look any brighter. This is a challenging cluster.

I can resolve 10 stars using direct vision, and double that number when I use averted vision. Going to 200x in the 11-inch raises my star count to 14 using direct vision. But

Steve Coe *is the author of* Observing Nebulae *(Springer-Verlag, 2006) and is a frequent* Astronomy *contributor.*

st globular clusters

this comes at the cost of making NGC 5053's background glow quite faint.

At the 2001 Texas Star Party, I viewed the cluster using a 36-inch f/5 Newtonian with an 11mm eyepiece. Even with all that aperture, I resolved only 36 stars. Save this difficult target for a night with exceptional seeing and transparency.

In the doghouse

In 1764, Charles Messier discovered the superb globular cluster **M3** (NGC 5272) in Canes Venatici the Hunting Dogs. *Burnham's Celestial Handbook* tells the story of how someone at Mount Palomar Observatory in California counted 45,000 M3 stars on photographic plate made with the 200-inch telescope. It struck me as a difficult job.

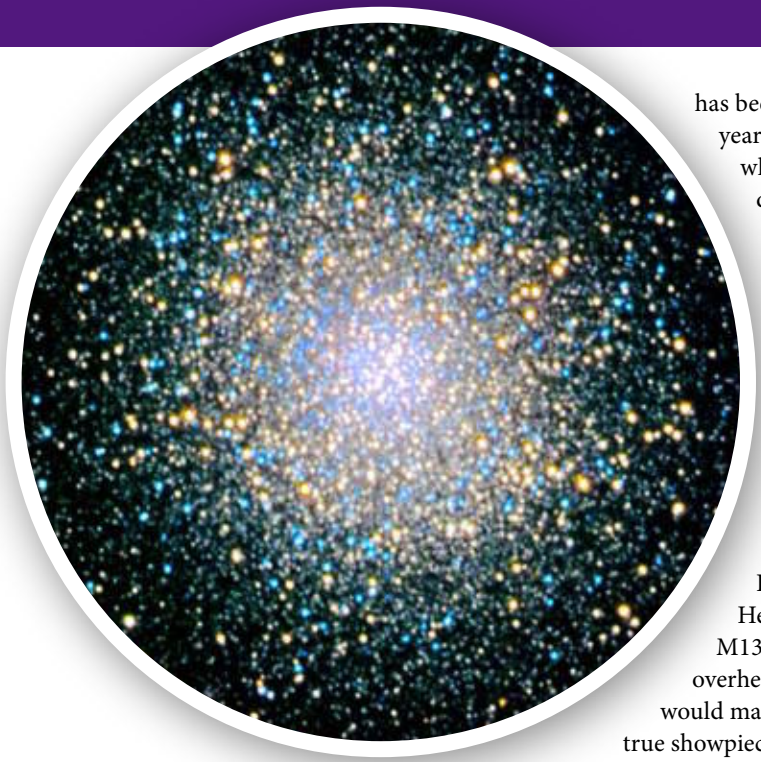
With a 6-inch f/6 Maksutov-Newtonian and an 8.8mm eyepiece, M3 appears bright, large, round, and much brighter in the middle. I resolved 19 stars, with another 10 at the limit of the scope and seeing. Averted vision doubles the cluster's apparent size. Using my 13-inch scope at 220x on a splendid night, M3's central brightness became more emphasized. I resolved 92 stars. The

HALF A MILLION STARS make M3 one of the largest and brightest globular clusters. M3 lies about 100,000 light-years away, but northern observers easily can see it in binoculars. NEIL FLEMING

NGC 5053 is one dim globular — the opposite of neighboring M53. Save this one for a night with exceptional seeing and transparency. MARTIN C. GERMANO

SEVERAL NICE STAR CHAINS render M68 a little ragged around the edges. The cluster lies 33,000 light-years away in Hydra. DANIEL VERSCHATSE

NGC 2419, about 180,000 light-years away, is held tightly by the Milky Way. Four 13th-magnitude stars conveniently box in this faint "star city." ANTHONY AYIOMAMITIS



ONE REASON the Great Globular Cluster in Hercules (M13) makes a splendid target is its proximity — it's just 25,000 light-years away. Hundreds of thousands of stars crowd a space about 150 light-years across. R. JAY GABANY

cluster's central arcminute was the only portion not resolved at this power.

When I raised the magnification to 330x with a 6.7mm eyepiece, the core became fully resolved. William Parsons, observing in the 19th century with his 72-inch Leviathan telescope, reported seeing dark patches in the cluster. They were clearly evident north and south of the core, about 3' on either side of center. The patches appear as thin, dark lanes that wind their way through myriad stars. M3 has been a favorite of mine for years. Give this cluster a try when your observing conditions allow the use of high power.

Enter the hero

M13 (NGC 6205) is one of the sky's finest globulars. It's easily resolved in small telescopes and simple to locate, on the western side of the Keystone asterism in Hercules the Hero. And, for Northern Hemisphere observers, M13 arcs almost straight overhead. These attributes would make any deep-sky object a true showpiece.

At a site about 60 miles (97 kilometers) from Phoenix, M13 is just visible to the unaided eye. It's about half the size of the Lagoon Nebula (M8) to the naked eye. In my 11x80 finder scope, I discern three layers of brightness, but I can't resolve the cluster into stars.

At 100x in the 13-inch scope, M13 is bright, large, and well resolved. Its center appears significantly brighter and slightly elongated. The most prominent star chains lead north and south. Silvery points sparkle against a globe of background stars.

My best view came at 220x. I counted 63 stars in the northeast quadrant, so I estimate the scope resolves some 240 stars at this power. Most are silver, a few are yellow or light orange. The famous dark feature of M13, called the "propeller," appears as a trio of dark lanes that intersect about 2' from the core. At 220x, I can spot these dark lanes with direct vision. Also, look for a chain of nine prominent stars that runs east to west across the core.

NGC 6229 is so bright it appears as a fuzzy spot in 10x50 binoculars. Using the 13-inch at 165x, the cluster appears as bright, reasonably large, and round with a brighter middle. Raising the magnification to 330x resolved five stars, the brightest being north of the core. Four fainter stars lie south of it.

M92 (NGC 6341) shares Hercules with M13. This is unfortunate for M92 because it's a big, bright cluster that's observed less often than its famous neighbor.

With the 11-inch SCT at 320x on a night with excellent seeing, I resolved 42 stars by direct vision and saw about 3 times as many using averted vision. M92 appears elongated and much brighter in the middle, with several short star chains curving out from the bright core. I think it resembles a "silvery scarab."

This object really benefits from averted vision, which brings out lots of faint stars. In fact, averted vision makes M92 look at least twice as large.

CURVED ARMS of stars make M5 in Serpens sparkle. Look for dark markings and a magnitude 13 triple star in the center. CHRIS SCHUR

PALOMAR 5 isn't much to look at. Galactic tides are pulling the cluster apart. This low-surface-brightness object is an observing challenge for large amateur scopes. CHRIS SCHUR

SPRINGTIME GLOBULAR CLUSTERS

Name	Right ascension (2000.0)	Declination (2000.0)	Mag.	Size
NGC 5139	13h26.8m	–47°29'	3.5	36.3'
M53	13h12.9m	18°10'	7.5	12.6'
NGC 5053	13h16.4m	17°42'	9.9	10.5'
M3	13h42.2m	28°23'	5.9	16.2'
M13	16h41.7m	36°28'	5.7	16.6'
NGC 6229	16h47.0m	47°32'	9.4	4.5'
M92	17h17.1m	43°08'	6.4	11.2'
M68	12h39.5m	–26°45'	7.7	12'
NGC 2419	7h38.1m	38°53'	10.3	4.1'
Palomar 5	15h16.1m	–0°07'	11.8	6.9'
M5	15h18.6m	–2°05'	5.7	17.4'

Three star chains curve out from the core. I believe these chains are what led William Parsons to comment on spiral structure in M92. The star chains snake their way from the cluster's center in three different directions in a manner that resembles a galaxy's spiral arms.

Hiding in Hydra

M68 (NGC 4590) in Hydra the Water Snake looks like a comet in my 11x80 finder scope. At 165x in the 13-inch, the cluster is bright, large, and compressed to a bright core. I describe its shape as "irregularly round," but not a perfect circle.

At 330x, I resolve 20 stars. Several occur in nice chains that make the edges of this globular appear ragged. This cluster is rich in faint stars.

Homeless no more

NGC 2419 isn't impressive in the eyepiece, but knowing what you're seeing adds to the view. This globular is so distant — about 180,000 light-years — astronomers once thought it had broken free of the Milky Way. For that reason, some dubbed it "the intergalactic tramp." In reality, the Milky Way has a tight hold on NGC 2419. The cluster has reached the farthest part of its elongated orbit around our galaxy.

In my 13-inch telescope at 220x, NGC 2419 has moderate size and brightness, with a brighter center. Four magnitude 13 stars "box in" the cluster. I have never resolved the cluster stars. The cluster's brightest stars are about magnitude 19, so it may take a 40-inch-aperture scope to resolve them.

The snake's surprises

Palomar 5, discovered in 1950 and located in Serpens the Snake, was one of several faint globular clusters astronomers discovered during the Palomar Sky Survey. Even in my 13-inch scope from a dark Arizona site, this low-surface-brightness object is tough to spot. At 100x, I saw it as extremely faint, moderately large, and lacking any brightness increase toward the center. Our galaxy's tides are shredding this globular.

NGC 6229, discovered by William Herschel in 1787, is 100,000 light-years away. It's bright enough to show as a fuzzy spot in 10x50 binoculars. CHRIS SCHUR

At the other end of the globular brightness scale, there's **M5** (NGC 5904). This has been one of my favorite globular clusters for years. One of my most memorable trips to dark skies involved driving to the Grand Canyon's north rim. On that night, M5 was discernible to the naked eye. Once I found the cluster in the 11x80 finder, I simply looked along the telescope's tube and — there it was.

At 100x, M5 looks bright and large, with a compact central core. A magnitude 13 triple star forms an isosceles triangle in the middle of the core. The cluster's curved arms of stars sparkle.

The cluster is rich in stars. At 220x, I counted 77 in the northwest quadrant. Extrapolating from this, I'd say observers can resolve at least 300 stars. This magnification also provides the best view of several dark markings within the cluster.

Spring is a great time to be out under the night sky with a telescope. So, pack up the scope and get out of town. Enjoy a vernal night viewing the Milky Way's ancient and varied "star cities." A

OVERLOOKED M92 IS AMONG THE BRIGHTEST GLOBULARS in the northern sky, but it pales in comparison to M13. Look for three star chains arcing from its core. BOB AND JANICE FERA

WEB EXTRA Download a Meade Autostar tour of these clusters at www.Astronomy.com/toc.

Light pollution and technological advances have forced many classic observatories to redefine their roles. /// BY JEREMY McGOVERN

How historic observatories will survive

Prior to Albert Einstein's first visit to the United States, his secretary presented him with two destination options: Niagara Falls and Yerkes Observatory. Asked which he preferred to visit, Einstein replied, "I would rather see Yerkes Observatory than visit Niagara Falls."

At that time, Yerkes Observatory in Williams Bay, Wisconsin, served as a leader in observational astronomy research. Yerkes continued contributing to astronomers' work after Einstein's visit, including research by astrophysicist Subrahmanyan Chandrasekhar and galaxy guru William Wilson Morgan.

If he could wander Yerkes' halls today, Einstein would find the observatory is still home to the world's largest refractor, but it isn't the premiere research location it was during his 1921 visit. Today, Yerkes hosts only one full-time researcher. With research at the observatory minimized, officials at the University of Chicago believed sustaining the observatory was no longer in UC's best interest.

THE CHAMBERLIN OBSERVATORY in Denver houses a 20-inch Alvan Clark refractor on a George Saegmuller equatorial mounting. UNIVERSITY OF DENVER

For sale: astronomical history

The University of Chicago announced in June 2006 it intended to sell the observatory property to Mirbeau — a New York-based hotelier. Through this sale, Mirbeau would acquire nearly 79 acres for $10 million and the university would eventually turn the observatory over to Williams Bay.

Mirbeau planned to build a spa, hotel, and housing development at Yerkes. After backlash over the sale from concerned residents, conservationists, and astronomers, Williams Bay's village board balked at the rezoning requirements essential to Mirbeau's plan. When it became apparent necessary zoning amendments lacked village board support, the sale collapsed, and the university formed a committee to develop a new plan.

Considering Yerkes' past, why would the university try to sell it? "Yerkes Observatory owns a wonderful place in the history of astronomy, but modern astronomy long ago moved on, and the university needs to stay focused on what we do best, which is advancing the frontiers of knowledge," explains former University of Chicago President Don Randel. Money raised from Yerkes' sale was to help fund a new facility for the university's Department of Astronomy and Astrophysics.

The leading culprits

External perceptions of obsolescence aren't exclusive to Yerkes — many historic U.S. observatories built during the 19th and early 20th centuries face similar issues because observational research has become less of a priority. What other factors have contributed to the dwindling studies conducted at many hallowed grounds of astronomy?

"Light pollution," says Robert Stencel, director of the Chamberlin Observatory at the University of Denver. "Sky glow is endangering every observatory." Stencel also serves as director of the Colorado chapter of the International Dark-Sky Association.

Many of the historic observatories were built before widespread nighttime electrification. Architects and planners of historic observatories in urban areas never could have anticipated the issues of sky glow that plague our skies today. For observatories built outside cities, urban sprawl brought light pollution, which enveloped these observatories decades ago.

"Sky glow has caused our night sky to disappear, and the public is unable to appreciate the night sky," says Stencel. "Without that appreciation of what's up there, public perception becomes less concerned about observatories and planetaria."

Jeremy McGovern *is an assistant editor of* Astronomy.

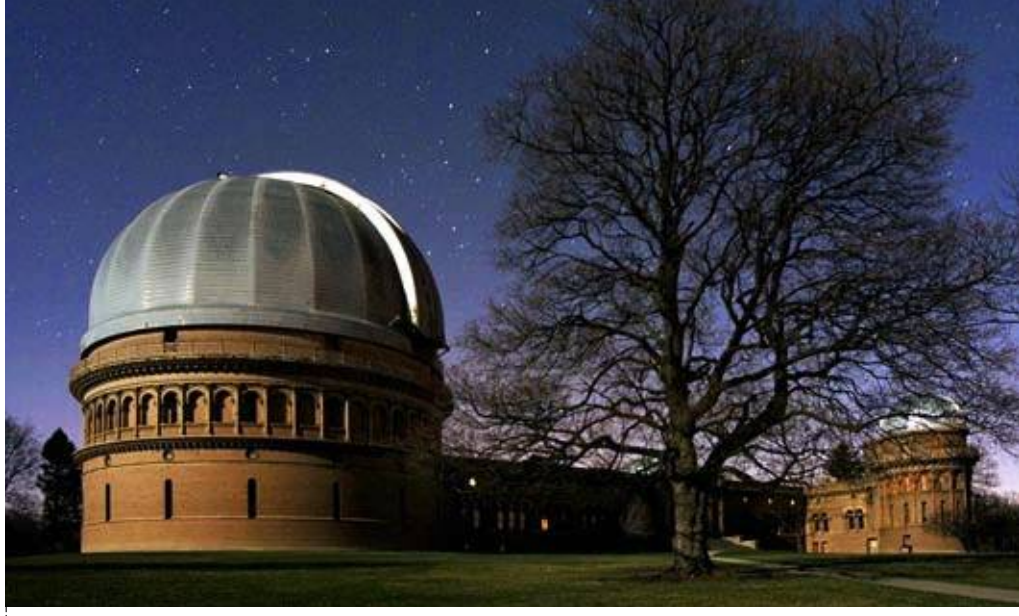
Funding affects historic observatories beyond the research conducted there, especially those affiliated with universities. The costs of operations, maintaining facilities, and restoration have forced many observatories to scale back and allowed property to fall into disrepair.

As with Yerkes, many facilities are tied to universities and must contend with other programs for funding. Although institutions may not sell the observatories, as the University of Chicago attempted to do, many sacrifice history for progress when it comes to financing operations.

Changes in how astronomers study the sky also have deemphasized America's historic observatories. Technology has advanced astronomical research. Modern facilities possess cutting-edge equipment, such as CCD spectrographs or infrared capabilities. Updating grand observatories with contemporary instruments is often impractical financially. Also, purists argue retrofitting antique telescopes with modern equipment betrays observatories' historic integrity.

That's not to say classic scopes are completely inferior by today's standards. "Optically, I believe they are superior to many instruments in the consumer market," says Trudy E. Bell of the Antique Telescope Society. "I'll take any Alvan Clark refractor over the latest go-to model. These scopes are to astronomers what a Stradivarius is to a violinist."

THE CINCINNATI OBSERVATORY, which opened in 1845, attracts the general public with events like ScopeOut. The 2006 ScopeOut featured activities that included solar observing. CINCINNATI OBSERVATORY CENTER



YERKES OBSERVATORY'S grounds almost transferred to a New York-based hotelier who wanted to build a spa, hotel, and dozens of homes on the property. After public outcry, the university rescinded its intent to sell and formed the Yerkes Study Group to develop a new plan for the observatory's preservation. ERNIE MASTROIANNI

Embracing a new role

To survive, historic observatories have adapted. They still are centers of astronomical learning, but the main focus for many has shifted from research to outreach. Through events, observatories now serve the general public. Largely staffed by volunteers from the amateur astronomy community, historic facilities throughout the U.S. now feature daytime and nighttime activities from observing to lectures to workshops.

"Our students still learn how to operate the scope, but research isn't a priority as much as group tours and our public nights program," explains Edward Murphy of the University of Virginia's McCormick Observatory. He is a member of the American Astronomical Society's Working Group on the Preservation of Astronomical Heritage. "The university realizes overall we are educators, not just to our students, but to our community. Our outreach efforts certainly factor into the decisions concerning our budget and preserving the observatory."

Although all are welcome to observatory open houses, some institutions concentrate their efforts on reaching children. "Kids aren't looking at the sky, so the observatory is a great portal for bringing people to astronomy," says Stencel. "We try to appeal to the public with our talks on subjects like constellations and cosmology."

To attract children to astronomy, facilities like the Cincinnati Observatory have teamed with national organizations like the Astronomical Society of the Pacific's (ASP) Project ASTRO and Family ASTRO programs.

Project ASTRO pairs observatory staff and volunteers with educators in their communities. Professional and amateur astronomers visit classrooms and provide hands-on activities, such as making a solar clock and building a lunar settlement. The goal is to encourage students to ask questions and think of themselves as scientists.

With Family ASTRO, participating observatories invite families to partake in activities similar to those Project ASTRO offers. Observatories hope to increase parents' involvement in their children's science education and curiosity of the sky.

"Through the ASP programs, we share the sky with people who may have never viewed a truly dark sky. We hope to foster an interest in astronomy that the observatory can continue to serve for years," says Niemi.

Your role

Preservation of historic observatories also rests with the amateur astronomy community. By voicing your concerns to local and state government and university administrators, contributing money, or simply showing your support at open house events, you will help ensure the legacy of America's grand observatories. After all, the public ultimately forced the University of Chicago to cancel its plan to sell Yerkes. And if Einstein were alive today, he might still prefer a trip to Williams Bay over Niagara Falls.

WEB EXTRA Read about a symposium created to save historic observatories at www.Astronomy.com/toc.

With a good solar filter, you can see sunspots, flares, and other hot stuff. /// **BY MICHAEL E. BAKICH**

How to observe the Sun

The Sun, because it's the brightest sky object, also is the easiest to observe. Put safety first, and even a small telescope will delight you with high-quality views. Plus, you can make good solar observations even when conditions rule out seeing other celestial objects.

Start with the disk

The **photosphere** is the Sun's visible surface and is the lowest observable layer of solar atmosphere. Observing the photosphere is easy through visible-light solar filters.

If the seeing (atmospheric steadiness) is good, you'll spot **granulation**, which observers describe as a mottled effect. Vast gas bubbles, whose centers are rising and edges are sinking, create granules.

Faculae are bright areas visible on the photosphere. Facula is Latin for "little torch." Faculae appear all over the disk, but observers most often see them near the solar limb. There, the contrast between the faculae and the darkened limb is highest.

Finally, look for a phenomenon called **limb darkening**. We observe limb darkening because the Sun is a sphere. Near what we see as the edge of the solar disk, the light must travel farther through the solar atmosphere. This causes the limb to be dimmer than the rest of the disk.

The chromosphere

The "sphere of color" lies just above the photosphere.

Here, hydrogen atoms emit energy called Hydrogen-alpha (Hα) radiation. Hα is reddish-colored light with a wavelength of 656.28 nanometers (nm).

Through an Hα filter, which allows only Hα light through, you'll see **prominences**, bright gas clouds ejected from the Sun and shaped by its magnetic field. Prominences appear as spikes, loops, "trees," detached regions, and more. Prominences look like dark lines silhouetted against the solar disk; astronomers call those lines **filaments**. Another Hα feature appears as bright areas around sunspots called **plages**.

Solar explosions

Also best seen through Hα filters, solar **flares** occur when the Sun's atmosphere suddenly releases built-up magnetic energy. Solar flares emit radiation storms and are the solar system's largest explosions.

Astronomers classify flares by how much area they cover at the time of maximum brightness.

THE CORONADO PST, available from Meade Instruments, is a complete Hydrogen-alpha telescope. *ASTRONOMY:* WILLIAM ZUBACK

Michael E. Bakich *is a senior editor of* Astronomy *who loves both visible-light and Hydrogen-alpha solar observing.*

Flares range from subflares (smaller than 2 square degrees) to Importance 4 flares, which cover more than 24.8 square degrees. On the Sun, one square degree equals roughly 57 million square miles (150 million square kilometers).

Dark areas in a sea of light

Sunspots, which are features of the photosphere, come in many shapes and sizes, according to the whim of the Sun's magnetic field. The field traps gas, slowing its motion and making it cooler than the surrounding area on the Sun's surface.

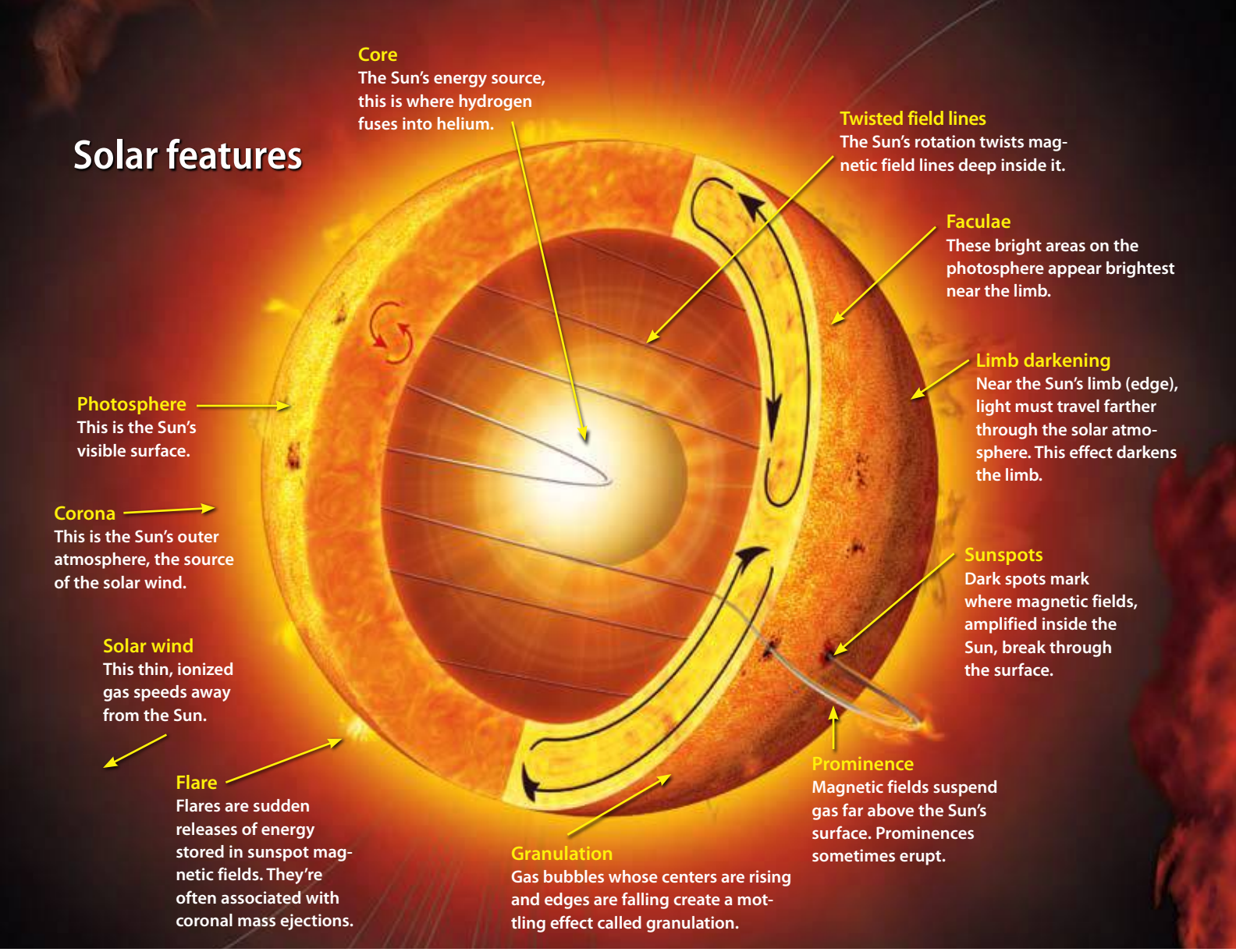
Usually, sunspots consist of a dark central region called the umbra surrounded by a lighter region known as the penumbra. The penumbra's temperature is typically 1,800° F (1,000° C) below that of the photosphere, and that of the umbra between 2,700° F (1,500° C) and 3,600° F (2,000° C) cooler than the photosphere.

Roughly every 11 years, solar activity peaks, resulting in greater numbers of sunspots and flares. German astronomer Heinrich Schwabe (1789–1875) discovered the sunspot cycle in 1843. This "11-year cycle" varies from as few as 9.5 to as many as 12.5 years. The start of any given solar cycle is defined as the minimum of solar activity. Since the 19th century, astronomers have recorded sunspot numbers each day.

In 1858, Swiss astronomer Johann Rudolf Wolf (1816–1893) published his formula for determining the daily sunspot number: k(10g + f); where *g* is the number of sunspot groups; *f* is the number of individual sunspots; and *k* is a calibration factor, different for each observer. To calculate your k-number, see this story's web extra at www.Astronomy.com/toc.

Observing by solar projection

One way to observe the Sun is by using an eyepiece to project the Sun's image. Some observers use an adjustable arm that holds


Solar features
Core
The Sun's energy source, this is where hydrogen fuses into helium.
Twisted field lines
The Sun's rotation twists magnetic field lines deep inside it.
Faculae
These bright areas on the photosphere appear brightest near the limb.
Limb darkening
Near the Sun's limb (edge), light must travel farther through the solar atmosphere. This effect darkens the limb.
Photosphere
This is the Sun's visible surface.
Corona
This is the Sun's outer atmosphere, the source of the solar wind.
Sunspots
Dark spots mark where magnetic fields, amplified inside the Sun, break through the surface.
Solar wind
This thin, ionized gas speeds away from the Sun.
Flare
Flares are sudden releases of energy stored in sunspot magnetic fields. They're often associated with coronal mass ejections.
Prominence
Magnetic fields suspend gas far above the Sun's surface. Prominences sometimes erupt.
Granulation
Gas bubbles whose centers are rising and edges are falling create a mottling effect called granulation.

ASTRONOMY: ROEN KELLY

a sheet of paper. Others use a box assembly. A box is a better choice because it darkens the surrounding area and increases contrast. In either case, the sheet of paper displays a 6-inch (150mm) circle — the standard size used by observers worldwide.

Mark the four directions, focus the Sun, and fit it to your circle. If it doesn't fit, either adjust the eyepiece/paper distance or choose an eyepiece with a different focal length. Don't use eyepieces with lens elements held together by cement because the Sun's heat will damage them.

Visual solar filters

A good solar filter is safe — it does not transmit harmful ultraviolet or infrared radiation. It also drops the Sun's brightness to a comfortable level.

Visible-light filters are either coated glass or optical-quality Mylar. The solar image through Mylar looks pale blue; through glass filters it can appear white, yellow, or orange. Glass filters are more expensive but more durable.

All solar filters fit over a telescope's objective (front) end. Some cover the entire objective (full-aperture filters), while others have smaller openings offset from center (off-axis filters). Off-axis filters eliminate secondary-mirror obstructions in Newtonian and catadioptric scopes. All solar filters should have round openings. Other shapes introduce distracting patterns.

Never use a solar filter that fits into an eyepiece. Some of these filters have cracked due to heat buildup (and it doesn't take long) and caused eye damage.

The most common solar filters transmit 0.001 percent of the Sun's light. This drops the Sun's brightness by roughly 12.5 magnitudes. Photographic-only solar filters with densities of 3 (7.5-magnitude drop) and 3.5 (8.75-magnitude drop) are also available.

Hydrogen-alpha (Hα) filters

Observing the Sun at the wavelength of Hα light is gaining in popularity. All Hα filters center on 656.3nm. However, such filters have different bandpass widths. The widest of these can be nearly 2 Angstroms (Å) and the narrowest 0.3 Å.

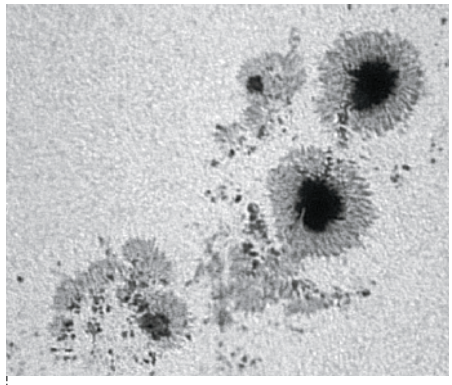
One Angstrom equals 0.1 nanometer. Prominences look great through a 1 Å-bandpass Hα filter, but chromospheric detail is low. Through a filter with a 0.5 Å bandpass, you'll see lots of chromospheric detail but few prominences. Some Hα filters are tunable; you can shift the bandpass' central wavelength slightly to either side.

Solar observing is addictive. Soon, you'll find yourself watching the Sun as much as the stars. Don't forget the sunscreen.

WEB EXTRA To learn how to classify sunspots, be sure to log on to www.Astronomy.com/toc.

Thanks to a wide array of solar filters, shooting high-quality solar images is a snap. /// **TEXT AND IMAGES BY DAMIAN A. PEACH**

Capture images of our local star



ACTIVE REGION 652 was a complex sunspot group. Peach used a 5-inch Meade refractor and a Baader ND5 solar-film filter to capture this image July 23, 2004.

For astrophotographers, what's not to

love about the Sun? Our daytime star is big, bright, beautiful, and can be photographed every clear day. It's the target of choice for lots of astronomers and offers dazzling images to amateurs using today's CCD cameras and webcams.

Imaging what we see

Photographing the Sun in visible light has never been easier or cheaper. Even a compact digital camera held at the eyepiece of a small telescope will produce images of the solar disk's spots and faculae.

Filters for visible-light imaging are widely available from suppliers. You can also use color filters (usually reserved for planetary viewing) for solar imaging. Green filters improve contrast of granulation and sunspots, while blue filters enhance faculae.

Small-aperture telescopes work well for solar imaging. In fact, the often turbulent daytime sky conditions will reduce the ability of larger telescopes to resolve anywhere near their limits. Apertures between 2.4 and 6 inches (60mm to 152mm) are ideal for visible-light solar imaging.

Imaging the invisible

Narrowband imaging is growing in popularity with today's amateur astronomers, particularly in the visible wavelength of Hydrogen-alpha (Hα) light.

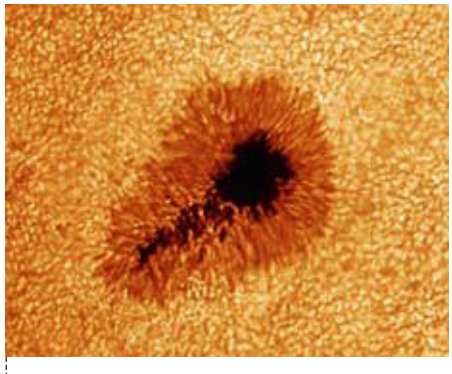
Hα filters reveal rapidly changing activity such as prominences and brightening due to solar flares. Through an Hα filter, imagers can capture short-lived details in the Sun's chromosphere.

One such exciting event occurs when huge solar flares fling coronal mass ejections (CMEs) into space. When aimed at Earth, these particle streams can disrupt communications and cause aurorae. CMEs appear in images as bright, saturated regions associated with sunspots. They change over the course of a few hours.

Hα filters are complex to manufacture and, therefore, often cost more than $2,000. One company, Coronado Instruments, has brought Hα imaging into the mainstream with its groundbreaking Personal Solar Telescope (PST). It costs $599.

Another company, DayStar Filters, sells narrower bandpass Hα filters for more serious observers. These filters work differently from the PST. You attach the main section

A SPECTACULAR PROMINENCE blasts off the Sun's surface in this Hydrogen-alpha image taken through a 4-inch refractor September 18, 2006.



THIS SUNSPOT IMAGE from September 8, 2006, shows a classic single spot surrounded by solar granulation. The author took this picture through a webcam attached to a 7-inch refractor.

AN IMPRESSIVE PROMINENCE erupts from the Sun's limb September 30, 2006. The author captured this image through a 4-inch apochromatic refractor with a 0.6Å Hα DayStar filter system.

to the telescope's focuser, and an energy rejection filter (ERF) fits over the telescope's objective or front opening.

Typical Hα filters for amateur astronomy range from 1.6 to 3.6 inches (40mm to 90mm) of aperture, and from 0.5 to 1.0 Angstrom (Å) bandwidth. (Manufacturers generally measure bandpass in Angstroms; 1Å equals 0.1 nanometer.)

The wider the filter's bandpass, the lower the surface contrast will be. For example, a 1.0Å Hα filter will provide excellent views of prominences, but weak contrast on surface details such as filaments.

A 0.5Å filter, however, shows excellent surface detail. Most amateurs select a 0.7Å filter, which is a good trade-off between the two extremes and provides excellent images of all Hα activity.

Imaging in Hα is straightforward. Selecting the correct exposure to capture both surface detail and prominences is difficult, however, especially in full-disk images. The prominences at the solar limb are always dimmer than the surface.

Solar imagers obtain good results using modest aperture Hα filters with webcams. With a large-aperture filter system, you can produce images that reveal a wealth of dynamic detail across the solar disk.

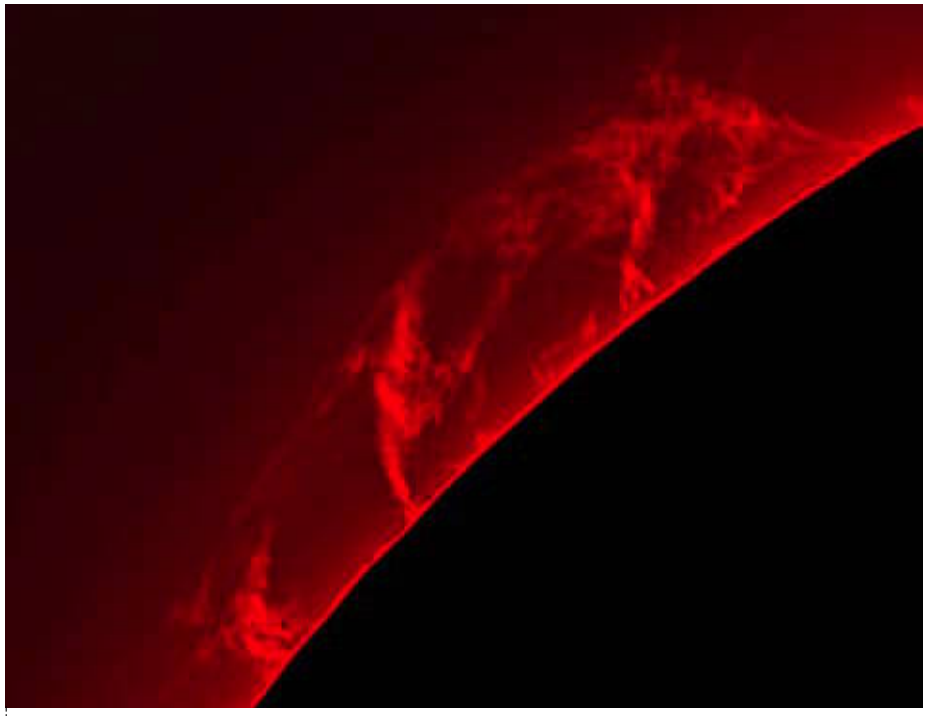
Contributing your work

Organizations such as the British Astronomical Association (BAA) and Association of Lunar and Planetary Observers (ALPO) welcome contributions from observers at all levels. Reports on and images of visible-light and Hα activity produce much useful information. For the solar sections of these organizations and how to contribute, see their web sites at www.lpl.arizona.edu/alpo and www.britastro.org.

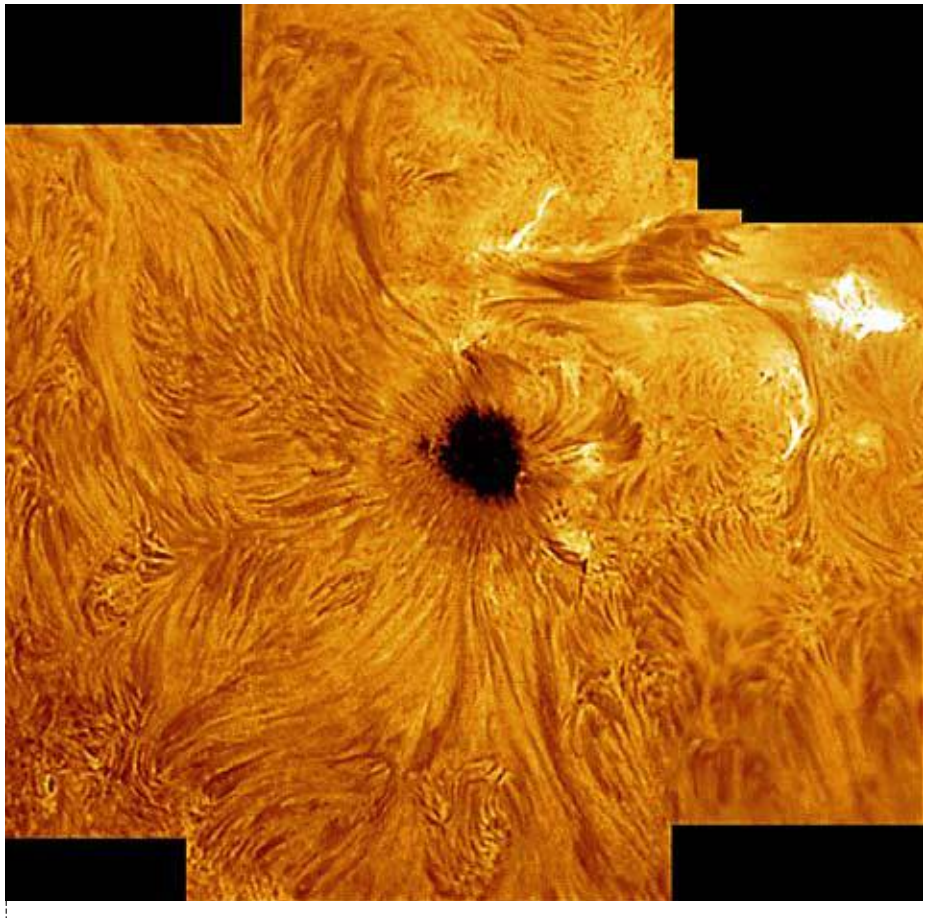
You'll find more tips from other observing groups such as "solarobservers" on Yahoo.com. Many active solar photographers share their images as well as observing and imaging techniques.

With the cost of imaging technology at an all-time low, and its user friendliness at an all-time high, there's never been a better time to get into astroimaging. By using high-quality filters, imaging our daytime star will keep you busy for a lifetime. A

Damian A. Peach *has captured thousands of solar images. See a variety of his visible-light and Hα images at www.damianpeach.com.*



THIS PROMINENCE CURTAIN unfolded December 16, 2006, at 10h23m UT. The author used a 6-inch f/9 apochromatic refractor and a DayStar 0.6Å Hα filter. He captured the image with a Lumenera LU075M CCD camera.



A CLASS C SOLAR FLARE erupts from a prominent sunspot December 9, 2006. The author captured this view through a 128mm Hα filter system and a webcam. The picture shows the brilliant eruption with the tangled, intricate detail common in Hα images.

Usually, observers don't describe 18-inch telescopes as compact and portable. This one, however, is both. /// BY JOHN SHIBLEY

Obsession's new 18-inch scope

Portable scopes, no matter their size,

are a necessity in this age of light pollution. It's not unusual for an observer to pack the car and drive miles to get away from urban sprawl. This creates a burgeoning demand for compact, lightweight, large-aperture scopes. Obsession Telescopes of Lake Mills, Wisconsin, has reached out to this market with its 18-inch f/4.2 Ultra Compact (UC) premium Dobsonian-mounted telescope. Its large-aperture brawn tears down into two assemblies that fit into a 26" by 26" by 20" (66cm by 66cm by 51cm) hard case. The truss poles take up no more space than a beefy fishing rod case.

Design details

What makes this design work is the unity of the whole. A single ring functioning as a secondary cage might seem a bit too shaved at the expense of rigidity. The same could be said of the six-truss approach instead of a conventional design that uses eight. And then there's the hinged altitude bearing: Has Obsession lost its mind and trimmed too much for the sake of compactness? Nope. When fully assembled, the Ultra Compact is like handling a precision touring bike.

The Ultra Compact does away with a conventional mirror box. In fact, the design combines the mirror cell, mirror box, and altitude bearing into one hybrid assembly. The gains from this approach are lighter weight and smaller size: A classical 18-inch Dobsonian reflector's lower box, mirror, and mirror cell combination tips the scales about 20 pounds heavier.

And the Ultra Compact's hybrid lower assembly, which Obsession dubs a "virtual mirror box," is only 14" tall (35.5cm) as opposed to 26" (66cm) for the standard design.

The hinged altitude bearing swings out and latches into place. Without this feature, the curved bearing would stick out about 7" (18cm) from its lower assembly, making the stack hard to stow in tight spaces like a car trunk.

The Ultra Compact throws in a simple innovation that makes me slap my head and wonder why no one else thought of it before. A hollow, 7" counterweight bar slips into a sleeve under the Telrad finder's mounting plate. It has a cap that screws into place, but the tube ships empty. You provide whatever weight medium you want to use. A 10-pound bag of #10 lead shot is small and effective. It costs about $30 from any shotgun-shell-reloading supplier. Can't find lead shot? Just use sand.

New features

The Ultra Compact also takes an unconventional tack with the truss poles that separate its upper and lower assemblies. Rather than using separated poles, Obsession connected the Ultra Compact's six trusses with

FOR TRAVEL, the Ultra Compact consists of a set of truss poles and a case that measures 26" by 26" by 20" (66cm by 66cm by 51cm).

/// SPECIFICATIONS

Obsession 18-inch UC

Focal ratio: 4.2
Focal length: 1,905mm
Mirror cell: 18-point suspension
Dimensions for transport: 24" by 24" by 13.5" (61cm by 61cm by 34.3cm)
Weight: 90 pounds (41 kg)
Eyepiece height at zenith: 70 inches (1.8 meters)
Includes: Feathertouch focuser, Telrad finder, external light baffle, and counterweight kit
Price: $6,540

TO PREVENT dew from collecting on the primary mirror and to eliminate stray light, Obsession provides a fitted shroud for the 18-inch Ultra Compact.

OBSESSION TELESCOPES' 18-inch UC Dobsonian-mounted Newtonian telescope will reveal incredibly faint deep-sky objects and show lots of detail on your "old favorites."

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hinges that expand like an accordion. Setup takes less than a minute.

On most conventional Dobsonian-mounted reflectors, the cage that houses the secondary mirror is a two-ring affair with rigid walls. The Ultra Compact's design reduces this to one ring that holds the secondary, finder, and focuser. The only inherent advantage to a traditional approach is blocked stray light. The Ultra Compact, however, includes a light baffle that secures with Velcro.

John Shibley *is a dedicated observer who observes from Sault Saint Marie, in Michigan's Upper Peninsula.*

I also discovered Obsession designed the assembled Ultra Compact to be intentionally out of balance. The telescope wants to swing and point straight up. At first, this seemed like a design oversight until it occurred to me that the scope balances only when there's an eyepiece in the focuser. In other words, you add the functional weight. Brilliant!

The Ultra Compact's altitude pivot point lies about a foot (30cm) above the virtual mirror box. This becomes a concern only if you want to add digital setting circles (Obsession's optional Argo Navis system) or drive and slew motors (the optional ServoCAT). To accommodate these additions, the Ultra Compact's lower assembly retrofits in minutes with a tangent bar assembly that accepts encoders and motors.

An optional nylon shroud ($159) is in reality a necessity. It curtails dewing and blocks stray light. I've run into problems with shrouds that stretch around a circular base, as with the Ultra Compact. They typically sag into the light path. Obsession gets around this by sewing a hoop into the shroud's base to keep it rigid.

It all boils down to ...

The Ultra Compact's optical quality is top-notch. When you've shelled out several thousand dollars on this premium reflecting telescope, you get impeccable primary and secondary mirrors with, in Obsession's case, laboratory documentation to prove it.

My "wish list" would include the large-aperture Ultra Compact that I could carry conveniently on airlines. I would like to see a shock-absorbent hard case that lets the entire lower assembly, with mirror, get checked as airline luggage. The compact Ultra Compact design seems to come oh-so close. What the Ultra Compact does offer, however, is high-quality engineering innovation the likes of which is tough to find anywhere else on the market these days.

THE MAIN MIRROR and its housing of the 18-inch Ultra Compact fold down into what Obsession Telescopes calls a "virtual mirror box" (VMB).

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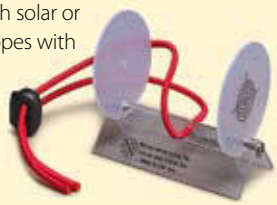

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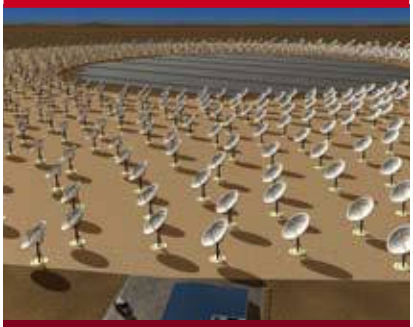

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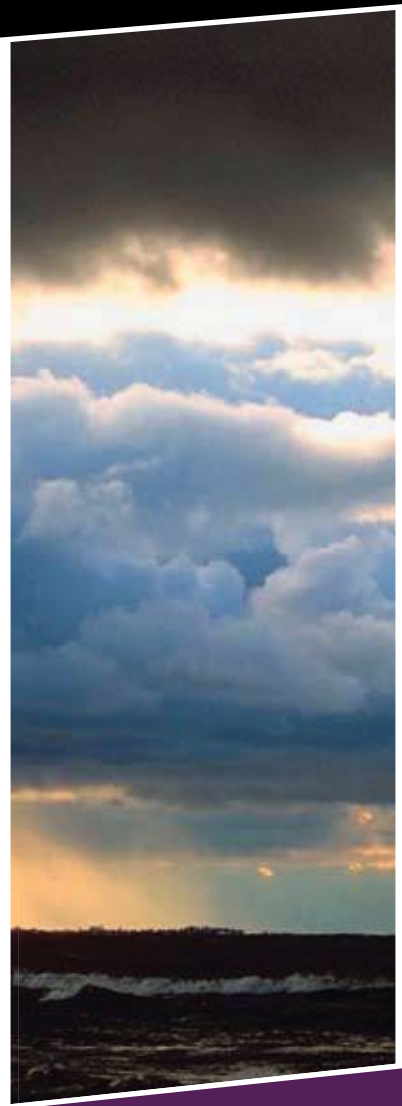

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LUNAR ECLIPSE SEQUENCE (3-inch Takahashi FC-76 apochromatic refractor, Canon 20D DSLR mounted at prime focus, various exposure times, taken August 28, 2007, from 2:30 A.M. to 6:35 A.M. MDT) /// **PETER LIPSCOMB, SANTA FE, NEW MEXICO**

TOTAL LUNAR ECLIPSE

Sun-Earth-Moon lineup

From our perspective, the three most important bodies of our solar system aligned again August 28, 2007, and a colorful drama played out in our sky. At such times, when Earth lies between the Sun and the Moon, the result is a lunar eclipse. The most precise lineups create total eclipses, such as the one pictured here. The continental United States experienced the eclipse in the predawn hours. If you missed the excitement of totality back in August — or the most recent total lunar eclipse February 22, 2008 — you'll have to wait more than 2 years for the next one. It occurs December 21, 2010.

FIND SPIRAL GALAXY M101 by heading 5.6° north-northeast of Alkaid (Eta [η] Ursae Majoris). Because of its low surface brightness, it's tough to see through a small scope. (14.5-inch RC Optical Systems Ritchey-Chrétien telescope at f/9, Apogee Alta U16M CCD camera, LRGBHα image with exposures of 360, 140, 140, 140, and 240 minutes, respectively) /// **JOHN SMITH, TUCSON, ARIZONA**

OPEN CLUSTER M67 in Cancer is one of the oldest known such objects. Although it shines at magnitude 6.1, it often gets ignored because it lies only 8° from the Beehive Cluster (M44). (6.2-inch Astro-Physics StarFire EDF apochromatic refractor at f/7.5, SBIG ST-2000XM CCD camera, LRGB image with 30-minute exposures each) /// **ANTHONY AYIOMAMITIS, ATHENS, GREECE**

SHARPLESS 2-82 in Sagitta is a combination emission and reflection nebula. The star HD 231616 excites the hydrogen, causing it to glow red. The blue light is reflected starlight. (16-inch RC Optical Systems Ritchey-Chrétien telescope at f/8.9, SBIG STL-11000 CCD camera, LRGB image with exposures of 120, 80, 80, and 80 minutes, respectively) /// **DON GOLDMAN, SHAVER LAKE, CALIFORNIA**

EMISSION NEBULA Sharpless 2-124 in Cygnus looks a lot like its nearby cousin, the Cocoon Nebula (Sh 2-125). Interstellar dust and gas between us and the nebula obscure much of Sh 2-124's detail. (7.2-inch Takahashi Epsilon 180 hyperbolic astrograph at f/2.8, SBIG ST-10XME CCD camera, HαRGB image with exposures of 420, 28, 28, and 28 minutes, respectively) /// **DEAN SALMAN, TUCSON, ARIZONA**

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IC5070, the Pelican Nebula, taken with the Orion 102ED f/7 refractor and a modified Canon 350D DLSR. Courtesy of Bryan Cogdell.

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